Potato Diseases in Oregon and Their Control

By M. B. McKAY

ROTATE!

Two plants same age from halves of same tuber; upper one grown on soil infested with Verticillium wilt from previous crop, lower one on soil which had not grown potatoes for five years.

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Oregon Agricultural College
Experiment Station

CORVALLIS, OREGON

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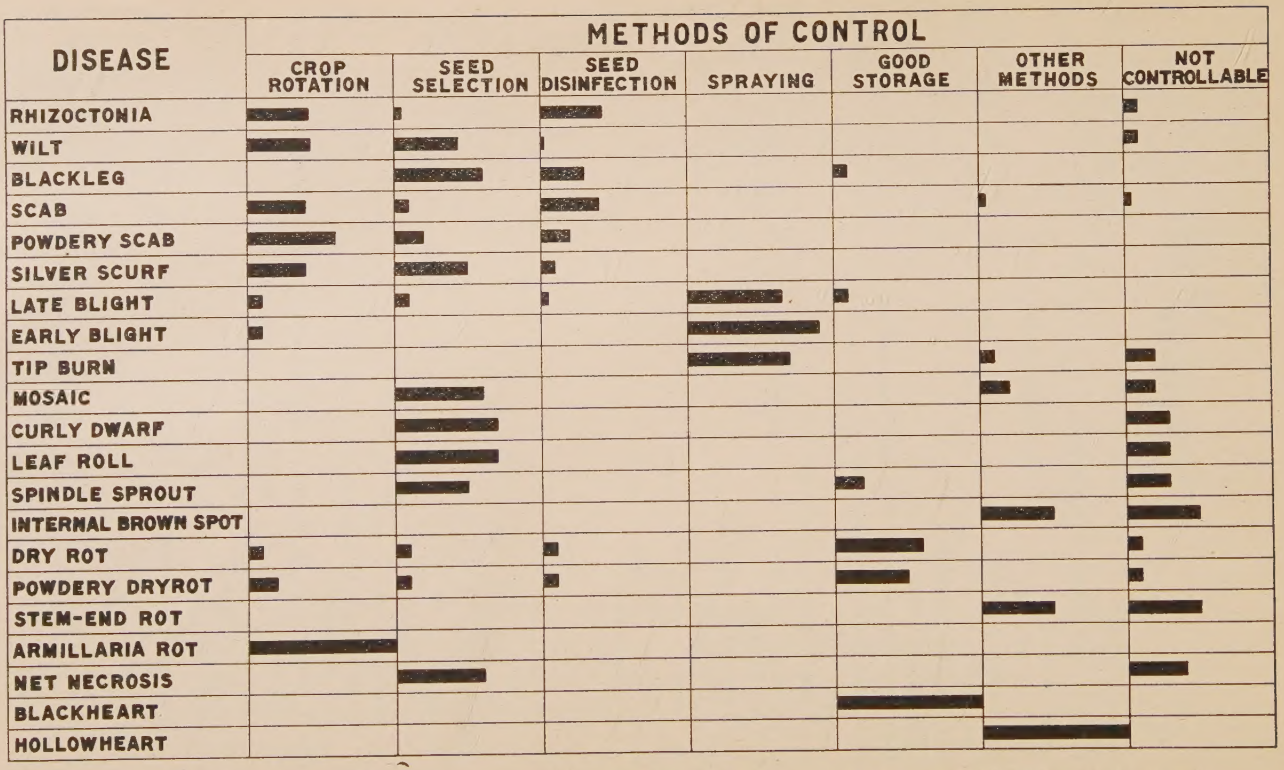

Fig. 1. Graph showing how potato diseases are controlled. The length of the bars shows the relative value of the different methods used.

Potato Diseases in Oregon and Their Control

By M. B. McKay

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INTRODUCTION

A comparatively few years ago, only three potato diseases were considered serious in the United States. Now there are recognized a half dozen generally serious diseases and a score of less important ones of very common occurrence, which occasionally are themselves quite serious. This comparatively rapid increase in the number of diseases affecting potatoes has been due in part to the continuous culture of potatoes on the same land for a period of several years. This unfortunate practice furnishes excellent conditions for the propagation of the common diseases and for the origination of new ones.

Potato growing is an important industry in Oregon and is generally a profitable one. The acreage in potatoes, however, and the average yield to the acre have been decreasing during recent years, particularly in certain sections of the State where soil diseases have been especially prevalent. This decrease in the production of potatoes has been very largely due to disease. Surveys of potato diseases made by the Oregon Agricultural College Experiment Station and correspondence with growers during the past few years in all of the important potato-growing sections of the State have shown that a surprising number of serious diseases are present in varying amounts and attacking from a few to 100 percent of the plants in different fields. As a result, of course, the yields have been greatly reduced as compared to what they should be when intelligent care is exercised in the prevention of these diseases.

To enable the growers to recognize and apply the proper control measures to the different diseases that may be attacking their potatoes and causing undue losses therein, it has been deemed advisable to prepare this circular briefly describing most of the potato diseases that occur in the State and giving the essential facts known concerning their control. A few diseases of great importance because of the damage they do to potatoes in other localities, such as wart and nematode, are described even though they do not now occur or are only very limited in their distribution in Oregon, in order that growers may be warned of their seriousness and may be on the lookout to protect themselves against them.

It is anticipated that the demand for information on the identification and control of the commoner potato diseases of Oregon will increase as a result of the movement toward official certification of potatoes, undertaken in Oregon in 1917 and continued with increasing interest and success to the present time. Certification was first begun in Wisconsin and has been successfully conducted for several years in a large number of other states.

GENERAL CONTROL MEASURES

Control Depends on Prevention and Not on Cure. It is fortunate that practically all of the diseases attacking the potato can be successfully controlled by comparatively simple and inexpensive measures. It should be borne in mind that the control of these diseases depends entirely on prevention and not on cure. If, for instance, a potato leaf is infected with late blight, it can not be cured of the disease, although the spread of this disease to other leaves or other plants can be prevented by thorough and timely applications of spray. And if the soil becomes contaminated with a disease-producing organism, disease prevention in this case consists in the proper rotation of non-susceptible crops for a sufficient length of time to starve out the parasite in the soil.

Five Important Control Factors and Their Relative Value. There are at least five important factors to be considered in the prevention and control of potato diseases; namely, crop rotation, seed selection, seed disinfection, spraying, and good storage conditions. There are other factors that have an influence on disease control, among which may be mentioned, kind of fertilizers used, cultural methods, controlling insects which aid in the spread of disease, the use of irrigation water, etc.; but the five factors mentioned first are the most important ones and will be discussed more in detail. All of these factors must be carefully considered if the grower is aiming at the production of potatoes high in yield and practically free from disease.

The relative value of each of these five measures for the control of the different potato diseases is shown graphically in Fig. 1. This set of graphs should be taken not as an absolutely accurate evaluation of the different control measures, though they are charted here on the basis of percentage, but it should be taken as an approximation of their value for disease control based on present information and our best judgment. When taken from this standpoint they are chiefly of value in indicating at a glance the measures which may be used to best advantage and which promise to give the best results for controlling the different diseases.

More Than One Measure Generally Necessary. The graphs show also that most of the diseases cannot be controlled by the use of one measure alone but that usually two or more measures must be employed before the most successful control can be expected or secured. A few cases will be mentioned briefly here.

Rhizoctonia lives over the winter in the soil and on the seed potatoes. For the control of this disease it is necessary therefore to use care in the rotation of the crops and in seed potato treatment. Failure properly to handle either of these factors would lay the crop liable to damage from the disease. Seed selection has only minor value in the control of this disease because it is next to impossible to sort out disease-free tubers and furthermore infested tubers are rendered harmless by proper treatment. And because the fungus attacks so many different hosts including some wild plants, it should be borne in mind that it is practically impossible to secure perfect control of this disease.

Again, the fungi which cause wilt are held over in the soil from one season to the next. They are also carried on the inside of tubers from diseased hills.

No seed treatment yet devised is effective in freeing these tubers of this internal infection, consequently control of this disease must be effected by seed selection, which in this case is best accomplished by the use of a seed plot where all diseased plants may be removed during the growing season while most easily detected, and by crop rotation. The standard seed treatment will kill only the organisms that are on the exterior of the tuber, therefore for wilt control it is of very minor importance. One of the organisms causing wilt of potatoes in Oregon occurs to some extent in the soil without any obvious relation to the crops grown thereon, making it unfeasible to obtain always complete control of the disease; though with good care in the use of the control measures mentioned this source of the disease will remain of minor consequence.

And further, the organism causing blackleg is not known to remain alive over winter in the soil, consequently crop rotation apparently is of no value for its control. Tubers from diseased hills are carriers of the organism both on the interior and on the exterior, from which it spreads more or less readily to other tubers in the bin or during the planting operations, frequently causing tuber rot. These sources for the introduction of the disease may be avoided by seed selection, preferably from a seed plot, and by seed disinfection. The conditions under which the tubers are stored also have some influence on the amount of blackleg rot which develops in storage. Any increase in the amount of blackleg rot in storage would in turn increase the chances of spreading the disease from these rotting tubers to other healthy ones to be later carried to the field in the seed potatoes. These and the other diseases will be discussed more fully below under the headings of the separate diseases. A brief presentation will now be made of the chief general control measures as enumerated above.

CROP ROTATION

Parasites Live on Potato Refuse in Soil. Inasmuch as a number of the organisms which cause diseases of the potato live for part of the time in the old tops and other refuse left in the soil after harvest, the practice of crop rotation is imperative where these diseases are present and a disease-free product is desired (see cover page). Not all fields grown continuously to potatoes for several years develop disease to a serious extent, because the seed used may have been free from disease, but such cases are very rare. In every section of the United States and of the world, in fact, where potatoes have been grown continuously or very frequently on the same piece of ground over a considerable area for a period of years, the result has always been the same; namely, that diseases became so severe that profitable yields could no longer be secured and large acreages had to be abandoned for potato culture.

Some Parasites Live Also on Wild Plants. Investigation and experience have shown in a number of instances that some organisms which are parasitic on potatoes occur on wild plants or in virgin soil never previously planted with any cultivated crop. Land recently cleared of timber or brush and placed under cultivation may serve as an illustration. In case such soil is immediately planted to potatoes an appreciable amount of disease including at least Rhizoctonia, scab, dry-rot, and Armillaria tuber-rot may result. Such soil, though it may be highly productive and may produce a satisfactory

crop of potatoes for table use, is nevertheless undesirable and should not be utilized the first year for growing a crop of potatoes to be used for seed. A better practice would be to grow other crops for two or three years before planting potatoes. Some potatoes grown in reclaimed dry land in Eastern Oregon, moreover, the first year under cultivation gave an appreciable amount of powdery dry-rot in storage even though stored in a newly constructed, well-ventilated cellar. Investigational work in Idaho has indicated that the organism which causes powdery dry-rot is at present apparently well distributed throughout western desert soils. Where some experiments were conducted on such reclaimed soils much better results were obtained by growing potatoes after alfalfa and grain rather than by placing potatoes on the land the first year in cultivation. From this standpoint, therefore, crop rotation means not merely that potatoes should not follow potatoes too closely but also that potatoes should not be planted on soil immediately following any other plants of whatever kind that harbor potato parasites. Before potatoes are grown the land should be planted with non-susceptible crops long enough thoroughly to rid it of these parasites.

Fig. 2. One good four-year rotation that may be used in a great many localities is corn, grain clover and potatoes. This may, of course, be varied if desired better to suit local needs. A longer rotation than this is more dependable and occasionally necessary for freeing the soil of potato parasites, whereas a shorter one is not effective for anything like complete disease control.

Three-Year Rotation Inadequate for Successful Disease Control. It is known that some of the organisms producing disease in potatoes remain alive in the soil for at least three years, even though no potatoes are grown on the land during that time. Consequently, it becomes necessary to practice longer rotations than this in order that the organisms may die out of the soil before potatoes are again planted on such land. It is best that potatoes be not grown on the same land oftener than once every four or five years, the ground in the meantime being planted to other crops not affected by the potato parasites. Since the length of the rotation and the kind of crops grown in rotation with potatoes will of course vary with each region and with the individual needs of each farm, no general plan to follow can be given. The chief considerations are to build up the soil by the use of legumes, to keep it in good working condition by the use of some cultivated crops, to avoid holding over disease-producing organisms in the soil by the use of non-susceptible crops, and, of course, to utilize the crops that will give profitable returns for the region.

One good six-year rotation that may be used in a great many localities is grain, clover, corn, grain, clover, and potatoes. Where especially good quality seed potatoes are used, this rotation may be shortened materially to corn, grain, clover, and potatoes (Fig. 2) or even reduced half. A three-year rotation, however, is not to be relied upon for anything like complete disease control if used over a considerable period of years. This is especially true if ordinary, poor potato-seed stock is planted. A longer rotation, as for instance corn, grain, clover and timothy two years, and potatoes is much more trustworthy. Common practice has demonstrated that the most reliable plan to follow is the adoption of some such well-designed crop-rotation system that is well suited to local needs, following it as a more or less regular practice. As a general agricultural practice, crop rotation has everywhere proved a necessity to successful farming.

SEED SELECTION

Seed Selection Helps to Improve Quality and Avoid Disease. One of the most important means for avoiding disease in potatoes consists in seed selection, as indicated in Fig. 1. This is true because wilt, blackleg, mosaic, leaf roll, and a number of other serious diseases are carried over from one season to the next on the inside of the tubers and cannot be eliminated by seed disinfection.

Seed selection should be practiced for three purposes; namely, increase in yield, greater uniformity in size and shape of tubers, and greater freedom from disease. The methods in each case are essentially the same, that is, the selection, either during the growing season or before general harvesting time, of hills which are free from disease, high in yield, and possessed of the desirable qualities of the variety under selection. By choosing such potatoes for seed the yield and vigor of the crop can be improved in quantity and quality to such an extent as to much more than offset any added expense for labor involved in the selection process.

Seed Selection Best Accomplished by Use of Seed Plot. If selection has not been made in the field before harvest, it is good practice to start the improvement of the potato crop by selecting from the bin for planting the following season tubers which are smooth, uniform, free from blemishes, and apparently free from disease, and which weigh between two and eight ounces. The selection of individual hills, however, is by far the most reliable and satisfactory method. One convenient way for accomplishing this is to set aside each year a seed plot of about one-tenth the total acreage, which will be large enough to produce all the seed potatoes that will be required for planting the general field the following year. All plants that are diseased, weak, degenerate, or off type, that belong to another variety, or are undesirable in any way should be rogued out (removed) during the growing season while the diseases, weaknesses, or varietal mixtures can be readily and accurately determined. In the case of the wilt disease it seems advisable to pull out at the same time not only the wilted hill but also the next healthy hill on either side of the wilted one in the same row in order to avoid the spread of the disease from one plant to another down the row. In this way only the more desirable plants will be left to mature and furnish tubers for seed. Out of these remaining plants in the seed plot enough of the high-yielding and most uniform,

typical hills from places in the field where there is a full stand should be selected at harvest time to be used for planting the seed plot the following year; the remainder can be planted in the general field. This simple but effective plan, of which a diagram is given in Fig. 3, furnishes a method of continuous improvement of the seed potatoes which in a few years, if combined with proper crop rotation and seed disinfection, will reduce most of the tuber-borne diseases to a negligible quantity and will greatly increase the average yield of potatoes.

Seed Plot Should be Isolated. The seed plot should if possible be in a separate patch isolated from the rest of the potatoes on the farm by at least 100 feet in order to avoid the danger of having some of the diseases spread from the general field to the seed plot. If desirable also the seed plot may well be planted on soil which is given a longer and better crop rotation than would be justified for use in the general field.

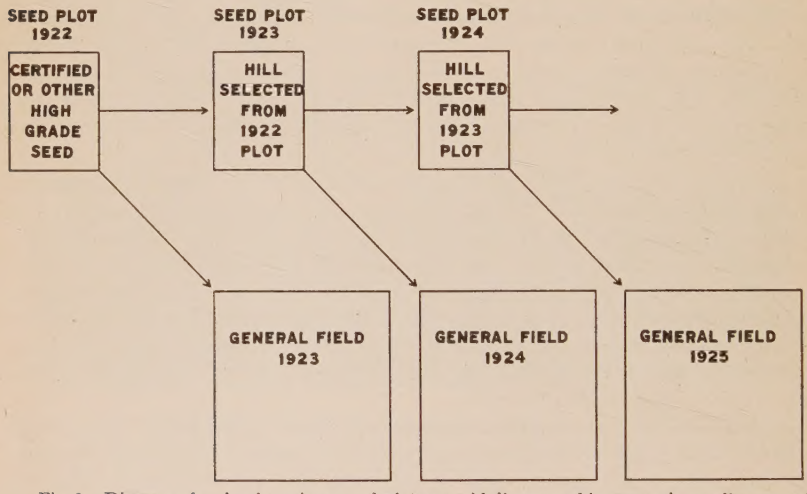

Fig. 3. Diagram of a plan for using a seed-plot to avoid disease and improve the quality of seed potatoes. For a beginning the first seed-plot may be planted with certified seed potatoes, with hill-selected seed potatoes from the previous year, or with bin-selected tubers if no better potatoes are available. The seed-plot should consist of about one-tenth of the total acreage of potatoes to be planted the following year.

All Potatoes Grown for Seed Should be Thoroughly Rogued. Ordinarily no particular advantage commensurate with the cost would be gained from roguing fields of potatoes which are grown only for table use. The presence of blackleg under some conditions when the danger of excessive tuber-rot in storage is too great might serve as an exception to this statement. The much-needed improvement of table potatoes should be accomplished mainly through the improvement of the seed potatoes used in producing these crops. The desirability of using great care in the production of the seed potatoes, therefore, can hardly be overestimated. Every field of potatoes grown for seed should be thoroughly and completely rogued. Every potato grower should pay more attention to this most important matter of seed selection. In every locality where home-grown seed can be maintained in

good productive condition from year to year the use of a seed plot should become a part of the general practice of every farm.

Only Standard Market Varieties Should be Grown. Seed selection, however, can not and should not be expected to overcome the paramount shortcomings or undesirable features of any particular variety. In other words, the efforts of growers toward improvement of the seed stock should be confined to the variety or varieties that are best suited to the local growing and market conditions. It is folly to spend time and energy on a second-rate variety of potatoes when much better financial returns could be secured by growing only the standard types. A grower, or still better a whole community, should aim to confine selection of potato varieties to only one or two standard market varieties rather than to a large number of non-standard varieties. The advantages to be gained from offering to the market large quantities, even several car-load lots, of well grown, high quality, and uniform potatoes would soon become apparent.

Certification of Seed Potatoes an Official Movement that Recognizes Value of Selection, etc., for Potato Improvement. The State of Oregon, through the Extension Service of the Oregon Agricultural College, is now giving official sanction to the movement for improving seed potatoes by selection, etc., by providing official inspection and certification of fields being grown for seed. The requirements for certification are such as to insure a product that may reasonably be expected to produce well. The requirements, on the other hand, are quite practical and are not too difficult for the careful grower to meet. The potatoes from fields which fulfill the requirements may be sold as certified seed under special official tags labeled "Oregon Certified Seed Potatoes." The practice is apparently firmly establishing itself because of the ability of the certified potatoes to produce so satisfactorily and so well as compared to the average lot of seed potatoes and because it furnishes a grower who wishes to secure a good lot of seed potatoes an opportunity to buy potatoes of a more or less standard quality. If seed-potato improvement work has not been carried on for at least a year or two on one's own farm or if one's own seed potatoes are not of particularly good quality, the securing of an amount of certified seed potatoes sufficient to plant at least the seed plot may well serve as the starting point for securing good-quality seed potatoes. Then if the seed plot is maintained each year not only will the losses from disease be reduced to a minimum but the average yield of the potatoes grown will be greatly increased.

SEED DISINFECTION

Some Diseases Carried on Surface of Tuber. Due to the fact that a number of skin diseases, such as scab, Rhizoctonia, etc., are so often present on the potatoes in this State, it is desirable that all potatoes, whether they show evidences of disease or not, be treated with a disinfecting solution before they are planted. Provided of course that the potatoes are not planted in soil already infected with disease-producing organisms, seed treatment not only will control these diseases mentioned but will also aid in controlling others, such as wilt, blackleg, dry-rot, etc. This is effected by killing the spores that may be on the surface of the potatoes and that, if not killed, might produce disease later on. Before treating any seed potatoes, however,

it is always best to run them over a slat-work sorting table or rack and discard all tubers which are bruised, cracked, or show evidence of decay. This will also remove much of the dirt, which interferes with the disinfecting solutions.

Mercuric Chloride Most Effective Material for Treatment. Recent experimental work on potato-seed treatment in a number of states and particularly in Utah and Wisconsin has shown definitely that Rhizoctonia, which is the commonest and most destructive potato disease in Oregon, is quite effectively controlled by the standard two-hour soak in mercuric chloride, but that it is not effectively controlled by treatment with formaldehyde. Mercuric chloride is also equally as effective as formaldehyde for scab control; consequently mercuric chloride should be adopted as the standard material for all potato-seed treatment in the State. Where, however, anyone wants to use formaldehyde for scab control alone or to avoid rot by treating the potatoes before placing them in storage in the fall, it may be employed at the rate of 1 pint (40 percent commercial formaldehyde solution) in 30 gallons of water, soaking the uncut potatoes for two hours and spreading them out at once to dry.

Mercuric Chloride Used in 1-to-1000 Solution. The mercuric chloride solution is prepared and used as follows:

Mercuric chloride (corrosive sublimate)..... 4 ounces
Water.....30 gallons

Soak the uncut or whole potatoes in this solution from one and one-half to two hours and dry before planting.

Dissolve the mercuric chloride crystals or powder in about a gallon of hot water in glass jars, stone crocks, or a wooden bucket before dilution. This formula makes a 1-to-1000 solution. It decreases in strength with use. To correct this, add ½ ounce of chemical for every 4 bushels of potatoes treated for two hours. If a shorter treatment is used, reduce proportionately the amount of chemical added. For instance, if treated one and one-half hours add ⅜ ounce; if one hour, add ¼ ounce. Time and convenience are conserved if the chemical added is handled in a stock solution, one ounce dissolved in two quarts of water. Keep the water in the tank up to its original volume. The solution can be utilized as long as it remains clear, usually for not more than seven or eight times. Wetting the potatoes for twelve to twenty-four hours before treatment helps to remove dirt, softens the sclerotia of Rhizoctonia, and makes the disinfection more effective. In using this mercuric-chloride solution it should be borne in mind that this material is very poisonous, and if potatoes are once treated with it they should never be used for human consumption or for feeding to animals.

If the planting is not to be done immediately after disinfection, the potatoes should be dried thoroughly before being placed in storage again. Care should be taken not to reinfect the potatoes by placing them back in the same bags or storage places unless they too are disinfected. (For disinfection of storage bin see page 19 under "Storage Conditions). The bags may be disinfected by soaking for one hour in formaldehyde, 1 pint to 15 gallons of water.

Treatment Conveniently Done in Barrels. Mercuric chloride corrodes metals and must be used in wooden barrels or tubs, asphaltum-painted iron, cement, or wooden tanks. One handy way is to have about three barrels

(Fig. 4) with a hole and plug at the bottom for convenience in draining the solution off after treatment. Two of the barrels can be kept constantly in use treating potatoes and the third one may be filled with fresh potatoes while the others are soaking. The better practice is to treat the potatoes loose in the solution rather than to have them in some container such as sacks, crates, etc. Recent work has shown that gunny sacks take more mercuric chloride out of the solution and thus weaken the solution faster than the potatoes themselves do.

Fig. 4. One convenient arrangement for the treatment of potatoes is the use of three barrels mounted on a platform. The solution can then be readily transferred from one barrel to another.

Solution Weakens with Use and Must be Kept Up to Strength. The mercuric chloride reacts with the organic matter of the outer portion of the tuber and so becomes weaker with each successive treatment. Table I, which is made from data given in Bulletin 331 of the Wisconsin Agricultural Experiment Station, shows the result of tests to determine the rate of weakening following several successive treatments. After the first treatment the solution was only 75 percent of standard strength, after the fourth it was only 46 percent, and after the twelfth consecutive treatment it was only 6.5 percent of standard strength. This shows well the need of taking steps to maintain the solution at a strength that will be efficient for disease control. A convenient method for doing this has been mentioned in a preceding paragraph. Other work has shown too that dirt and refuse that may be carried into the solution with potatoes that are not well cleaned will weaken the solution much more than the potatoes themselves do. This emphasizes the desirability of at least using the precaution to run the potatoes over a slat-work sorting table to get out all of the dirt and trash possible. If this is not done the solution may be weakened excessively, become inefficient for further use, and give unsatisfactory results.

TABLE I. LOSS OF STRENGTH OF MERCURIC CHLORIDE WITH TREATMENT OF 12 CONSECUTIVE LOTS OF POTATOES [1]

Treatment	Percent of standard strength [2]
	%
Original solution	91.0
After 1st treatment	75 0
After 2d treatment	66.0
After 3d treatment	57.0
After 4th treatment	46.0
After 5th treatment	35.0
After 7th treatment	26.0
After 9th treatment	16.0
After 12th treatment	6.5

[1]From Bulletin 331, Wisconsin Agricultural Experiment Station.
[2]Standard strength solution of mercuric chloride is 4 ounces to 30 gallons of water, or 1 part of the chemical to 1000 parts of water.

Seven and One-half Gallons of Solution Required to Cover One Bushel of Potatoes. Thirty gallons of solution will treat about four bushels of loose potatoes at one time, and so if used eight times will treat about thirty-two bushels. If, however, the potatoes are placed in sacks while treating, which is not so desirable a method because of the more rapid weakening effect on the solution, then thirty gallons used eight times will treat on the average only about twenty-six bushels of potatoes.

Potatoes Should be Treated Before Cutting. It is the safer and better practice always to treat the potatoes before cutting, and not after they are cut, as occasionally the seed pieces are apparently considerably injured by the solution if treated after being cut. This has been shown both by experimental work and by the general experience of growers. In cutting potatoes, it is advisable to have for each cutter two knives, which, when not in use, are to be kept with their blades immersed in about a ten-percent solution of formaldehyde. When cutting, reject every tuber which shows any signs of disease or discoloration of the interior, especially near the stem end. Not all tubers which show discoloration are affected by a disease-producing organism, but since many of them are it is safer to discard all such tubers and not to run any undue risk in the matter. Drop the knife used in cutting the discolored tuber into the formaldehyde at once to prevent infecting other seed with it and take out the other knife to use until another suspicious-looking potato is cut.

Hot Formaldehyde Solutions Used for Scab Control in Some States. This opportunity should not be passed by for mentioning recent experimental work conducted in a number of states on the use of hot solutions for short periods of time for the control of Rhizoctonia and scab on potatoes. One method said to be satisfactory particularly for scab is in brief as follows:

Use formaldehyde at the rate of 2 pints to 30 gallons of water. Dip potatoes for two minutes at 118° to 122° F. Pile treated potatoes six to eight inches

deep, cover with wet sacks for one hour, and then allow to dry. The solution should not be warmer than 122° F. because this would injure the germination of the potatoes, nor should it be cooler than 118° F. as it would then not control the disease if the tubers are dipped for only the two-minute period.

Effectiveness of Hot Solutions not Tested in Oregon. It is easily seen that there are some advantages and some disadvantages in a method like this. The work of treating the potatoes could be done in a much shorter time, though the equipment necessary would be more elaborate and closer attention would have to be paid to details in order to guard against injury and to insure the efficiency of the treatment. No tests have been conducted by the Oregon Agricultural College Experiment Station using hot solutions, and the efficiency and superiority of these methods have not been sufficiently demonstrated in other states to justify Oregon growers in using any of these methods on a commercial scale in preference to the standard two-hour mercuric-chloride treatment without first trying them on a small scale.

SPRAYING

Bordeaux Mixture Used for Spraying Potatoes. In order to control certain of the leaf diseases such as late blight or early blight, spraying of the potato plants must frequently be resorted to. For this purpose bordeaux mixture has proved to be the most efficient spray mixture used, of which the following formula is most frequently employed and is apparently best for potatoes:

Copper sulfate (Bluestone)	5 pounds
Lump lime	5 pounds
Water	50 gallons

This is briefly and commonly expressed as 5–5–50 bordeaux. A weaker solution, such as 3–4 50, may often be used with good results if it is thoroughly applied.

Bordeaux Mixture Should be Used as Soon as Made or Else Preserved with Sugar. A convenient and satisfactory method of making up this spray mixture is to dissolve the 5 pounds of copper sulfate in 25 gallons of water either by suspending it in a sack near the top of the water over night, or in a small quantity of hot water, as it dissolves slowly; slake the lime gradually in a small amount of water and dilute the milk of lime to 25 gallons, then pour the two solutions together into a third barrel or through a strainer directly into the spray tank and stir vigorously. The resulting mixture is bordeaux and is of a milky blue color. The spray mixture should be strained as it is put into the spray tank, since otherwise the small particles held in suspension are very apt to clog the spray nozzles and cause considerable trouble. The spray mixture is then ready for use and should be applied at once. If it is impossible to spray at once due to bad weather or other unfavorable conditions, three quarters of an ounce (a heaping tablespoonful) of sugar dissolved in a small amount of water should be added to each barrel of 50 gallons of spray mixture. This will keep the spray mixture in good condition for a long time, even two or three months, though without the sugar added the mixture would have lost most of its value and become practically worthless in even one day's time.

Bordeaux Mixture May be Conveniently Made From Stock Solutions. In case large quantities of bordeaux mixture are to be used, it will be found convenient to make up stock solutions of the copper sulfate and lime at the rate of one pound in one gallon. To prevent undue evaporation these stock solutions should be kept well covered when not in use and should always be well stirred up before any is removed for making bordeaux mixture. Then when 5–5–50 bordeaux is desired, 5 gallons of the copper-sulfate stock solution and 5 gallons of the milk-of-lime stock solution may each be diluted with 20 gallons of water and then stirred together thoroughly, making 50 gallons of the desired spray mixture. These solutions should not be mixed for the bordeaux, however, until it is to be used immediately as it loses value if lef. standing for more than a few hours, unless sugar is added as mentioned abovet

Spray Should be Applied from Three to Five Times During Season. The largest increases in yields as the result of spraying have been secured when the spraying was begun while the plants were from six to eight inches in height and continued at intervals of about every two weeks. Much benefit has been derived, however, by commencing later in the season and spraying only three times. In Oregon probably the only disease for which spraying should be done regularly is late blight, though both early blight and tip burn can also be successfully controlled by this means. The first application of spray should be made at least by the time the disease first appears.

When the plants are from six to eight inches in height it will require approximately 75 gallons of spray mixture per acre to cover the plants well and give good control. Later when the plants are larger from 100 to 125 gallons of spray will be needed.

Spraying Must be Thoroughly Done to be Effective. A convenient and satisfactory spray machine is one that will maintain at least 100 pounds of pressure, that will spray thoroughly four rows of potatoes at a time, and that is geared to the truck or run by an engine. The spraying should be thoroughly done, using preferably three nozzles to each row, one from above and one on each side (Fig. 5), since the plants must be completely covered with the fine mist in order to be effectively protected. The spray machines which are equipped with only one nozzle for each row of potatoes are not adequate for covering the entire foliage of the plants with the spray and will not effectively protect them from infection. Such machines are better than nothing but should be used only when it is impossible to secure the more efficient three-nozzle attachments. For small home garden plantings the hand barrel spray outfit which requires one person at the pump and one to handle the nozzle is sufficient for good blight control, provided the work is thoroughly and carefully done.

Lime-sulfur Not Satisfactory for Potato Disease Control. It should perhaps be stated that lime-sulfur should not be used for spraying potatoes. This material does not give as good results in controlling the late-blight disease, and furthermore when used on potatoes it causes an actual stunting of the plants and a reduced yield as compared to unsprayed plants. Bordeaux mixture, on the other hand, has a stimulating effect on the growth of the plants, giving increased yields even though no disease is present on the plants.

Dusting a Promising Method for Late Blight Control. That spraying for late blight control is effective and profitable in many sections has been

demonstrated over and over again, yet the practice has not been as universally adopted by growers anywhere in America as the practicability of the method would justify. One reason for this is that spraying is a rather inconvenient task to perform. Dusting, on the other hand, as compared to spraying, is much more conveniently done and requires much less expensive and complicated machinery for applying. This has led to a very great interest in the possibility of the substitution of dusts in place of liquid sprays wherever possible. During the past few years a number of experiments have been conducted in Canada and in some of the northeastern states on the dusting of potato plants for late blight control. This work, while it is yet in the experimental stage, has indicated that the dust, if properly applied, may be counted on to give at least approximately as good blight control as the spray.

Fig. 5. Spray machine showing a good arrangement for the use of three nozzles to each row of potatoes. (*Illustration by courtesy of Bateman Manufacturing Company.*)

Sanders' Copper Lime Dust Tested Most Extensively. The most extensively tested combination of materials for dusting potatoes is the one known as Sanders' Copper Lime Dust consisting of 15 pounds dehydrated, finely ground copper sulfate, 8 pounds calcium arsenate, and 77 pounds hydrated lime. When there are no insects to be killed, a mixture of 15 pounds of copper sulfate and 85 pounds of lime may be used. About 50 pounds of this dust mixture would be required to the acre for each application in order to equal in amount the metallic copper contained in the 100 gallons of bordeaux mixture necessary to give good control of blight on full-grown plants. Proportionately less than this amount would be required when the plants are smaller. The schedule as to the number and frequency of dust applications will not differ from that of spraying so far as known at present.

Dusting is More Conveniently Applied and May not Cost More than Spraying. The materials required for dusting an acre of potatoes cost more

than those necessary for spraying an acre, yet the dust can be applied more quickly and with cheaper equipment and when all items of the cost are computed it may cost but little if any more to dust potatoes than to spray them.

On the basis of equipment necessary for application, dusting has the advantage over spraying, particularly for the small grower, for a hand duster, even though it does not have the distributing efficiency of the good power duster, may be used with good results on acreages up to three to five acres, whereas no hand sprayer is satisfactory for this size of field.

Dusting Has not Been Tested in Oregon. It is, of course, impossible to predict what the future of potato dusting will be. Some who have watched the experimental work closely believe that eventually it will almost, if not completely, replace spraying, and will become far more general among potato growers than spraying ever has. No tests have been conducted on its applicability to Oregon conditions. The subject has been mentioned here because of its promise for the future and in order that any grower who is interested may test for himself the efficiency and convenience of the method. If dusting is undertaken it should be tried out on a small scale, maintaining adequate checks so that an accurate estimate of its value may be obtained.

STORAGE CONDITIONS

Storage Losses Held Down by Low Temperatures and Good Ventilation. A considerable part of the loss of potatoes due to disease is brought about by various tuber-rots in storage. There are a number of distinct rots of potato tubers caused by different organisms, and without exception they are most severe when the storage temperatures are high and when the air becomes heavily laden with moisture due to lack of proper ventilation. For instance, neither the powdery dry-rot which is so prevalent and serious in the eastern part of the State, nor the dry-rot which is apparently widely distributed all over the State, will develop seriously in storage if the temperature is kept from 35° to 40° F., and the storage place is kept well ventilated. It is also well known that the shrinkage in weight of potatoes in storage is much greater when the temperatures are allowed to remain high than when they are kept down to 35° to 40° F. These facts show the necessity of surrounding stored potatoes with the proper storage conditions in order that the serious losses from storage rots and from shrinkage in weight may be avoided.

Potatoes in large quantities should never be placed directly in storage if they have become heated by high day temperatures. They should first be thoroughly cooled to prevent as far as possible the natural heating which takes place and to start the storage period under as favorable conditions as possible. This cooling may often be done with convenience and economy by leaving the potatoes outside the storage place until well cooled by night temperatures and then moving them into storage either late at night or early in the morning before they have had an opportunity to become heated again by external conditions.

Good Storage Places are Necessary for Trustworthy Storage. A good storage place embodies the following requirements: ease and thoroughness of ventilation, ability to prevent rapid changes in temperature inside in response to rapid changes in the temperature of the atmosphere outside, convenience in cleaning, conveniently arranged for use, ample in size, and durable. In

many sections of the United States where potatoes are an important cash crop these essentials are most efficiently secured in the cellars constructed mainly underground and partly above, with three or more ample-sized ventilators in the top, and with large doors and a driveway at one end large enough to accommodate a wagon for loading and unloading the potatoes.

Another type of storage place used with much satisfaction in this State is the double-walled, well-insulated bin with the walls about six inches thick and with ventilators to let air in beneath the potatoes and out at the top; these ventilators, when the days are warm, may be left open at night and kept closed in the daytime, with the result that the whole bin is kept reasonably cool all the time. All storage places should be provided with a thermometer, so that the temperatures may be regulated intelligently. Injury is produced

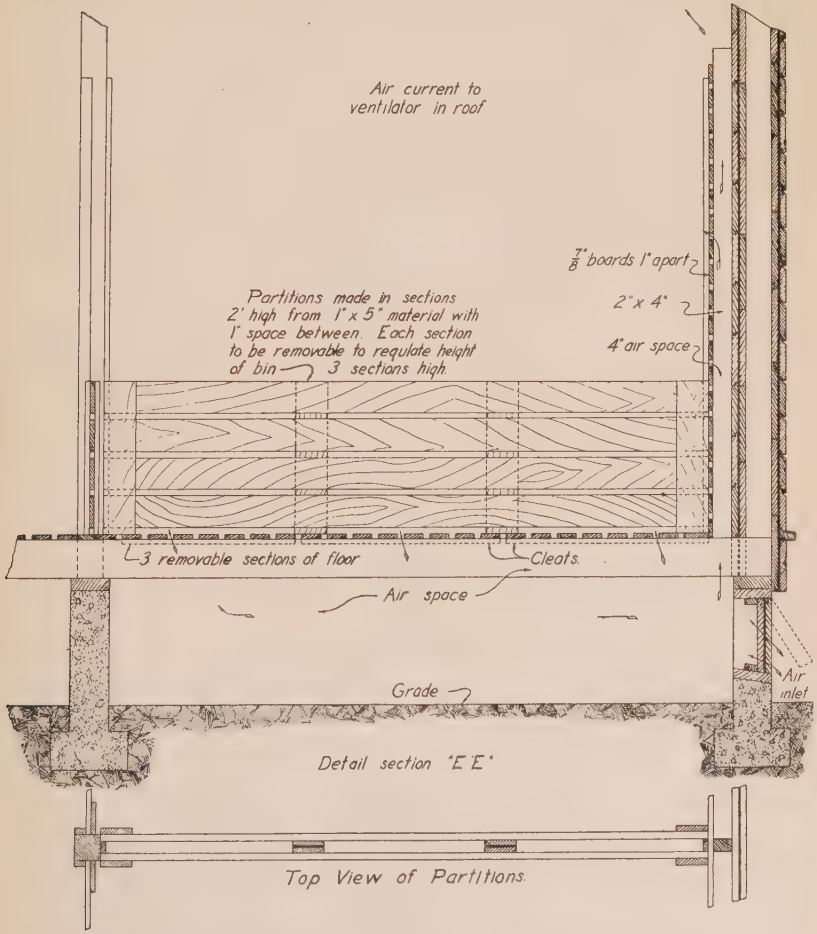
Air current to ventilator in roof
7/8" boards 1" apart
2"x 4"
4" air space
Partitions made in sections 2' high from 1"x 5" material with 1" space between. Each section to be removable to regulate height of bin
3 sections high
3 removable sections of floor
Cleats
Air space
Grade
Air inlet
Detail section "E E"
Top View of Partitions

Fig. 6. Section of potato bin showing one plan for the construction of the slatted walls, floors, and bin partitions to give good ventilation, which is so much desired in potato storage.

when the temperatures are too low as well as when they are too high. With the dry-rot it appears that the critical time, the time when many of the infections and when much of the loss from this disease results, is during the first two months after digging, when the temperatures are likely to be higher than during any other part of the storage period. It is at this time that our potatoes need especially to be surrounded by the favorable storage conditions that are best secured only in a good storage place. Whenever possible the storage place should be located in a dry, well-drained place, and preferably away from a sunny slope, so as to avoid unduly high temperatures.

Bins Are Best Made up with False Slatted Walls and Floors. As an aid to thorough ventilation, the lack of which is now responsible for much of the poor storage in the State, all permanent potato storage places should be equipped with bins made of slatted floors, walls, and double slatted bin partitions. For convenience in taking down the bins when emptied of potatoes, these should be made in sections. They may be constructed after plans shown in Fig. 6 or to suit particular needs. In any event the division walls should be double, with an air space between them. The ventilated wall and floor may be constructed of three-inch board strips, allowing a one-inch space between boards, and separated from the main floor and wall by joists and studding. This type of bin construction provides a conduit for air on the side wall and, connecting with the bottom, affords an air passageway completely around the stored tubers, materially lessening the danger from tuber heating and from tuber-rots in storage and providing a convenient and sanitary bin which can be taken down easily, cleaned, and disinfected when desired.

Bins Should be Cleaned and Disinfected Before Potatoes are Stored. In order to kill all the rot-producing organisms already present, storage places, particularly those in which rotting of the potatoes was bad the previous year, should be thoroughly cleaned and disinfected before potatoes are again placed in storage. To accomplish this, the storage places may be swabbed or sprayed with either of the following solutions:

Copper sulfate (Bluestone) . 1 pound Water . . . . . 10 gallons	or	Formaldehyde . . . . . 1 pint Water . . . . . 10 gallons

After being disinfected the storage place should be well aired and dried out before potatoes are again placed in it.

POTATO DISEASES

Accurate Recognition First Step to Successful Control of any Disease. The first step in the successful control of any disease is the accurate recognition of the symptoms or appearances of the particular disease under consideration. Before one can progress far toward the accurate identification of most of the potato diseases it is necessary to give a careful and complete examination of the entire plant, noting specifically the color, shape, size and condition of the leaves; the soundness and condition of the stems, such as rotting or cankerous areas, discolorations of both the inner and outer tissues, above and below ground; the condition of the seed piece, and the presence of any abnormalities on the roots and the new tubers. At times a microscopic or cultural examination of affected tissues must be resorted to before a reliable

determination can be made. It is of course not expected that the general grower will do this and it is mentioned here only to show that when the diseased plants have an appearance other than that which is average or typical then some difficulty may be experienced in the identification of the disease. One may occasionally encounter a disease which is not included in the circular.

Key Designed to Aid in Identification of Potato Diseases. As an aid to growers in determining what diseases may be affecting their potato crops the following brief "Key for Identifying Potato Diseases" has been prepared. Having found a plant or tuber affected by a common disease in the typical way and having accurately noted the symptoms, this key will no doubt be of assistance to the grower in the recognition of the disease. Following the key will be found a more complete though necessarily condensed description of the different specific diseases, together with the definite measures that are recommended for their control.

Though of course some diseases affect both plants and tubers, the key is divided for convenience into two parts: (1) Diseases Affecting Plants and (2) Diseases Affecting Tubers. Some diseases are therefore listed under both groups. For those who are not familiar with the use of such a key it may be explained that it is arranged in "steps" of equal rank, as A, B, and C, and under each of these 1, 2, and 3; and in steps of unequal rank, as A, 1, and a. The correct procedure is to read the steps of equal rank, as A, B, C, etc., until one is found to fit the specimen under examination; then drop down to the next unequal step below and read the steps of equal rank with this one, as 1, 2, 3, etc., until the specimen is properly located, or if a further subdivision is made drop down to the final rank and select the description which fits the specimen. Then, having the name of the disease, turn to the more complete description and the illustration of the disease on the following pages for checking up on the accuracy of the determination and for the information desired on the nature and control of the disease.

As an illustration of the method for using the key let us suppose we have a plant with no conspicuous spots on the leaves but with leaves rolling or drooping and yellowing, stunted in size, with lower end of stem affected by black rot, and the seed piece entirely rotted. Under "I. Diseases Affecting Plants," A does not fit, B fits; as a precaution we may look at C but it does not fit. Under B, 1 fits, 2 and 3 do not fit. Under 1, "a, Lower part of stalk especially below ground inky black and rotten. Plant easily pulled up. Seed piece rotten, usually in pulp. Occasionally soft rot in some of the tubers. Blackleg." This appears to fit our specimen exactly and we look at the more complete description of the disease on pages 25-26 for a confirmation of our determination and for the information that is desired on its nature and control.

KEY FOR IDENTIFYING POTATO DISEASES

I. **Diseases Affecting Plants.**

A. Foliage showing prominent circular or irregular dead areas not confined to lower leaves.

1. Dead areas at first circular or irregular spots within leaf blade or on part of margin. May finally involve whole leaf.

a. Spots brittle, light to dark brown, small (one-eighth to one-half inch in diameter), more or less circular,

usually showing concentric rings giving spot a "target board" effect. *Early Blight.* Page 40.

b. Spots large, water-soaked, dark brown when dry, sometimes with light green margin and showing grey mildew on lower surface of leaf; abundant in wet weather, sometimes killing foliage completely. Found usually late in season though in some localities as early as June. *Late Blight.* Pages 37-40.

2. Dead areas not circular or irregular spots within leaf blade, confined at first to tips and margins of most exposed leaves and working inward. May finally involve whole leaf. Dead spots harsh, dry, and curling up, and leaves inclined to roll on midrib. Appears only after very warm, sunny weather and often following insect injury.
Tip Burn. Page 51.

B. Foliage showing evidence of disease in wilting, rolling, crinkling, dwarfing of, or loss of color in leaves with no prominent dead areas or if present confined to lower leaves.

1. Leaves wilting or rolling or both usually accompanied with change of color from green to yellow or brown. Plants usually stunted and dying prematurely.

a. Lower part of stalk especially below ground inky black and rotten. Plant easily pulled up. Seed piece rotten, usually in pulp. Occasionally soft rot in some tubers. *Blackleg.* Pages 25-26.

b. Stalk firm and normal appearing on exterior but with inner tissues stained brown in streaks at least as far up as surface of ground. Seed piece often sound. Brown discoloration in vascular region at stem end of some tubers. *Wilt.* Pages 32-34.

c. Stalk firm and without discoloration either on exterior or interior. Roots showing small swellings or knots varying up to ¼ inch in diameter scattered irregularly over entire root system. Some tubers in hill slightly pimply on surface with small circular brown spots in tissue about ¼ inch below surface.
Nematode. Pages 34-37.

2. Leaves more or less rolled without wilting or extensive loss of color.

a. Plants often normal in size. Rolling most conspicuous on upper leaves which may show yellowish or brownish tints but usually no general yellowing. Aerial tubers and enlarged nodes on stems common. Dry reddish brown scars on stem below ground, on stolons or roots. Slight whitish growth appearing like salt deposit on green stems a short distance above soil

line. Many small potatoes common with some tubers usually showing black sclerotia scattered irregularly over surface. *Rhizoctonia.* Pages 26-32.

b. Plants more or less dwarfed. Lower leaves always rolled, leathery or brittle, often dying from tips backwards. Other leaves may roll also. Plants have stiff upright habit or are bushy and are almost always pale in color. Yield very small and tubers usually attached close to stem.

Leaf Roll. Page 49.

3. Leaves mottled with faint yellowish-green areas and crinkled or corrugated but not rolled or wilted.

a. Leaves slightly crinkled or corrugated and mottled with faint yellowish-green areas. Veins on under side of leaves sometimes black. Plants tending to be erect and rather stiff, not conspicuously dwarfed, except in severe cases. *Mosaic.* Pages 48-49.

b. Leaves strongly crinkled or corrugated, dark green with no conspicuous yellowish-green areas. Veins on under side of leaves frequently black. Plants extremely dwarfed and somewhat resembling curly kale. *Curly Dwarf.* Page 49.

C. Foliage normal or nearly so in appearance; stalks numerous, small and spindling, often considerably branched and showing no external or internal discoloration; tubers very small and occasionally very numerous. *Spindle Sprout.* Page 49.

II. **Diseases Affecting Tubers.**

A. Tubers exhibiting abnormalities, such as spots, discolorations, rots, etc.

1. Tubers showing abnormalities other than rot on exterior.

a. Rough, more or less round, corky, scabby, brown spots from ¼ to ½ inch or more in diameter scattered irregularly over surface of tuber. *Scab.* Page 42.

b. Small, roundish, slightly raised spots usually less than ¼ inch in diameter, epidermis around margin of spot torn and rolled back exposing brown, powdery mass of spores. *Powdery Scab.* Pages 42-43.

c. Irregular brownish stained areas on skin of tuber, which turn silvery and show many fine black points when moistened. Spots ¼ to 1 inch or more in diameter, usually most abundant on stem-end half of tuber.

Silver Scurf. Pages 43-44.

d. Black sclerotia from size of pin head up to ¼ inch in diameter, scattered irregularly over surface and attached to skin of tubers, particularly noticeable

when wet, looking like dirt but will not wash off though may be scraped off with finger-nail, leaving skin smooth. *Rhizoctonia.* Pages 26-32.

e. Brown to black, spongy, rough, warty outgrowths on tuber starting usually at eyes and varying greatly in size though frequently as large as walnut or even involving whole tuber. *Wart.* Pages 41-42.

f. Small slightly-raised pimple-like elevations on surface of tuber about ⅛ to ¼ inch in diameter which when abundant produce a very irregular, roughened and warty appearance. At varying distances usually not more than ¼ inch in tissue beneath such elevations are small circular brown spots usually less than 1/16 inch in diameter with pearly white center. *Nematode.* Pages 34-37.

g. Slightly raised enlarged openings in skin filled with light or cream-colored growths of cells appearing as though pushed out from below and which assume a corky appearance in older stages or when exposed to air for a few hours after digging. *Enlarged Lenticels.* Page 53.

2. Tubers showing abnormalities on interior; exterior normal.

a. Discolored strands or ring varying from light yellow to brown or black extending for varying distances into tuber at stem end from point of stolon attachment and confined to vascular tissues which when normal appear as faint layer located about ¼ inch beneath skin. *Wilt.* Pages 32-34.

b. Irregular brown spots varying in size up to ½ inch or more in diameter occurring in scattered and irregular places in interior of tuber. *Internal Brown Spot.* Pages 51-52.

c. Extensive network of small brown strands of discolored tissue extending throughout interior of tuber though occurring more abundantly in tissues near surface. *Net Necrosis.* Pages 49-51.

d. Irregular area of dead black tissue in interior of tuber. *Black Heart.* Pages 52-53.

e. Hollow areas occasionally surrounded by brown corky cells in center of tuber. *Hollow Heart.* Page 53.

3. Tubers affected by rot.

a. Slightly sunken dark-colored rotted areas of irregular size varying from very small spots to areas involving whole surface of tuber and extending into tissues usually not deeper than half an inch at harvest time,

though finally (particularly in storage) whole tuber may become affected.

Late Blight Rot. Pages 37-40.

b. Large sunken areas of brown firm rot occurring on any part of tuber and frequently starting at wounds, often involving large part of tuber. Surface of affected portion of tuber much wrinkled and often bearing numerous bluish or white protuberances.

Dry-rot. Pages 44-45.

c. Large sunken areas of brownish dry-rot extending into tuber in irregular way, and often containing pockets or cavities partly filled with a pink powdery mass of fungous growth. Surface of affected portion of tuber much wrinkled and often bearing pinkish or whitish tufts of fungous growth.

Powdery Dry-rot. Page 45.

d. Small to large rotting areas slightly sunken and light brown with few long black string-like strands attached to surface, interior rotted portion composed of alternating layers or flakes of yellowish and white tissues. *Armillaria Rot.* Pages 45-46.

e. Soft slimy rot frequently starting at stem end or at wounds and eventually affecting whole tuber.

Blackleg Rot. Pages 25-26.

f. Rot of tuber at stem end varying from slightly sunken and withered condition to soft and jelly-like light brown colored rot extending back at times 1½ inches from stem end. Rot affects only long tubers.

Stem-end Rot. Pages 46-47.

B. Tubers exhibiting no evidence of disease either externally or internally. Inspection must be made of growing plants for trustworthy determination of presence of these diseases in tubers.

Mosaic. Pages 48-49.
Curly Dwarf. Page 49.
Leaf Roll. Page 49.
Spindle Sprout. Page 49.
(Occasionally) *Wilt.* Pages 32-34.

DISEASES DUE TO PARASITES

The diseases are here grouped quite arbitrarily according to cause. Under parasitic diseases are listed the diseases of the potato known to be due to living organisms on or within the tissues of the potato.

BLACKLEG, *Bacillus phytophthorus* Appel. The common name of this disease is taken from the appearance of attacked plants. In typical cases the diseased plants die in the early part of the season due to an inky black, relatively dry decay of the main stalk progressing up from the point where it is

attached to the parent tuber. (Fig. 7.) The seed piece is invariably rotten, usually in a pulp. Plants less severely attacked or not affected till later in the season produce potatoes which if harvested and planted are very apt to carry the disease over to the next season. In the field before digging or later in storage, some of these tubers may develop a soft slimy rot due to the blackleg organism (Fig. 8). From such tubers the organism is readily spread by contact to healthy tubers in the bin, which if planted untreated may give rise to disease in the field. It is believed that this is the chief means by which the disease is transmitted from one season to the next. It is not definitely known whether or not the organism which causes the disease lives from one year to another in the soil, though experiments which have been conducted indicate that it does not.

Fig. 7. Blackleg. Plant showing the black rot progressing up from the lower end of the stem. (*Photo by W. C. Whitaker.*)

The disease can be very effectively prevented by planting only treated seed from healthy hills. If selection of healthy hills for seed has not been practiced during the past season, then surely all partly rotted potatoes in the bin should be sorted out and discarded and the remainder treated according to the suggestions given under "Seed Disinfection."

RHIZOCTONIA OR BLACK SCURF, *Corticium vagum* B. & C. This disease, which frequently goes by the name of black scurf due to the presence of black sclerotia or resting bodies of the fungus on the potato tubers at harvest time (Fig. 9), is apparently the commonest and most serious potato disease in the State. The disease manifests itself in a variety of ways, the most important of which are the following:

Often the young sprouts are attacked and are "burnt off" by the fungus even before they reach the surface of the ground. This may lead to the production of other new sprouts which in turn are also burnt off with the result that a rosette or cluster of sprouts is formed with their tips killed, none of which reach the surface of the ground and are able to produce plants (Fig. 10). This is often the cause of poor stands.

Plants attacked less severely or later in the season may develop lesions or dead areas on the under ground stems (Fig. 11) and upon the stolons, which so

interfere with the normal growth and functions of the plant that the leaves may roll up considerably, small potatoes may form in the axils of the leaves

Fig. 8. Soft, slimy field-rot of tuber produced by a plant affected with blackleg.

or other convenient places in the top of the plant (Fig. 12), or the nodes of the stems may become considerably enlarged and knobby because the starch cannot be properly transported downward, and a large number of small potatoes and a few large knotty ones may be developed underground. This result often gives rise to the term "little potato" disease. The yields in such badly attacked hills are practically worthless for commerce as well as for seed.

Fig. 9. Sclerotia or resting bodies of Rhizoctonia on surface of tuber. This is Oregon's most destructive potato disease.

Near the base of attacked plants and extending up varying distances from the ground surface, a gray or white mold-like growth on the surface of the stalks (Fig. 13), may frequently be found from late June to the last of August. This is the fruiting stage of the fungus in which numerous spores are produced and often has the appearance of salts collected on the stalks from the soil. The tops of such plants generally show distinct evidences of abnormalities due to the attacks of the fungus.

Fig. 10. Burning off of young sprouts due to Rhizoctonia. This is often a cause of poor stands.

Fungus Occurs on Other Plants than Potatoes. The fungus often attacks other plants than the potato, though generally much less severely, therefore long rotations are essential to hold the disease in check when it is once well established in the soil. The experience of many growers has shown that a three-year rotation will not free the soil of this fungus and that rather heavy losses may be expected from this disease under such conditions. A five-year rotation is much superior and should be used wherever practicable. Because the fungus attacks so many plants even including some wild ones in virgin soil, perfect control of the disease cannot be secured. If reasonable

care is taken in the application of the control measures presented in this circular, however, the losses from this disease will on the average not be large.

Seed Treatment with Mercuric Chloride Necessary to Free Tubers of Disease. In order to kill the Rhizoctonia sclerotia and mycelium on the surface of the tubers and thus avoid the introduction of the disease into the field with the seed potatoes, potato seed treatment is necessary. Because of the effectiveness of formaldehyde for scab control and the general familiarity of the growers with this method of treatment, and because for some time no better method of treatment was known, formaldehyde has been rather extensively used for treatment of seed potatoes against Rhizoctonia. Experiments conducted during the last ten years in many different states and under different conditions have clearly demonstrated, however, the ineffectiveness of formaldehyde for Rhizoctonia control and the superiority of mercuric chloride over all other methods yet devised for this purpose. The general effectiveness of mercuric chloride treatment for the control of Rhizoctonia has been so clearly and so well shown that no one should hesitate now to use this treatment in preference to all others.

Fig. 11. Brown dead cankerous areas on stalk and on stolons due to Rhizoctonia. The stalks are occasionally completely girdled. (*Photo by W. C. Whitaker.*)

Fig. 12. Small potato-like growths (aerial potatoes) in top of plant due to severe attacks by Rhizoctonia on the underground portions of stalks. (*After Bailey.*)

Comparative Seed Treatment Tests Conducted at Corvallis. It remains true, however, that quite a number of growers in Oregon are still using formaldehyde for potato seed treatment. This is so probably because they have not yet learned of or fully appreciated the superiority of the mercuric chloride treatment. On account of this fact a seed treatment test was conducted by the Oregon Agricultural College Experiment Station at Corvallis in 1920 to secure records under Oregon conditions that could be presented to Oregon growers.

Fig. 13. Rhizoctonia. White moldy growth, the fruiting stage of the fungus, on a stalk above the ground surface. (*Photo by Corsaut.*)

Two lots of Burbank seed potatoes selected out of the same bin were used. One lot of tubers was selected as being free of any Rhizoctonia so far as their appearance to the naked eye was concerned. No doubt they did have some Rhizoctonia present but to all ordinary appearances they were free from this fungus. All of the tubers selected for the other lot had Rhizoctonia sclerotia present on the surface.

These two lots of potatoes were divided, treated by several different methods, and planted on well rotated land to avoid contamination from the soil so far as possible. The formaldehyde solution for treatment was used at the strength of 1 pint of the commercial 40-percent formaldehyde in 30 gallons of water, which is the standard strength for scab control, and the mercuric chloride was used at the standard strength of 4 ounces in 30 gallons of water. Wooden barrels were used in making the treatments, since the mercuric chloride reacts with metal and consequently should never be used in metal containers.

At harvest all the different lots of potatoes were dug separately and the percentage of the tubers bearing sclerotia of Rhizoctonia were determined by counting all the tubers which were apparently free of Rhizoctonia and those which had sclerotia present. A summary of the results from this work is given in Table II and the accompanying graph. These show several interesting facts among which the following may be emphasized.

Formaldehyde Not Effective for Rhizoctonia Control. Where Rhizoctonia was present on the seed potatoes, treatment with formaldehyde for 1½

and ½ hours gave crops that were not very much freer of the disease than where the infested seed was planted untreated, the percentages of tubers bearing Rhizoctonia in the crops being 53, 62, and 85, respectively. Formaldehyde then is here shown to be far from effective in controlling Rhizoctonia.

TALBE II. RESULTS OF SEED TREATMENT TESTS AT CORVALLIS FOR CONTROL OF RHIZOCTONIA ON POTATOES

Season of 1920. Burbank Variety.

Condition of seed	Treatment	Time	Percentage of tubers bearing Rhizoctonia in yield
		hrs.	%
Apparently clean.....	Untreated.....	0	34
Apparently clean.....	Mercuric chloride.	1½	14
Rhizoctonia on surface.	Untreated.....	0	85
Rhizoctonia on surface.	Formaldehyde...	½	62
Rhizoctonia on surface.	Formaldehyde...	1½	53
Rhizoctonia on surface.	Mercuric chloride.	½	32
Rhizoctonia on surface.	Mercuric chloride.	1½	17

Mercuric Chloride One and One-half-hour Treatment Gave Best Results. Treatment with mercuric chloride for only one-half hour gave much better results than were secured with formaldehyde 1½-hour treatment, the comparative percentages of disease being 32 and 53, respectively. By far the best results where diseased seed was used came from the 1½-hour treatment with mercuric chloride, the percentage of disease in the crop in this case being only 17. These figures would indicate that the longer treatment with mercuric chloride should be used wherever possible. There are circumstances under which one might be justified in using the shorter ½-hour treatment, as for instance when the seed is only lightly infested or when the seed is badly sprouted and the injury to the sprouts from long treatment might be excessive. Seed potatoes should be treated while still dormant for then no injury to the tubers will result even when soaked for from 1½ to 2 hours, which is the standard length of time for treatment with mercuric chloride.

Apparently Clean Seed not Entirely Free of Rhizoctonia. Where apparently clean seed was planted untreated a considerable amount, 34 percent, of the tubers in the crop was diseased. This is largely accounted for by the fact that the Rhizoctonia fungus was no doubt present, as it is frequently known to be, in the form of indistinct thread-like filaments on the surface of the tubers not easily visible to the naked eye. These filaments, though small and indistinct, are capable of remaining alive on the surface of the tubers and introducing the disease into the new crop provided the seed is planted untreated. This fact illustrates the necessity for the recommendation which the Oregon Agricultural College Experiment Station is urging upon all potato growers in the State; namely, that all seed potatoes regardless of whether they appear to be diseased or not ought to be given the standard mercuric chloride treatment before planting.

The "apparently clean" seed when treated with mercuric chloride for 1½ hours gave in the test only 14 percent disease in the crop, which was only slightly less than that secured in the crop from the diseased seed treated in the same way (17 percent). To some these amounts of disease in these two crops may appear to be excessively high. It should be remembered, however, that Rhizoctonia is a more or less constant inhabitant in our soils and affects a wide range of plants besides potatoes, making it next to impossible to grow a crop of potatoes free from this fungus. No doubt the organism responsible for the disease on these crops came largely if not entirely from the soil. This only emphasizes the necessity for carefully conducting the cropping systems so as to avoid undue accumulation of this as well as other diseases in the soil, as has already been outlined in previous paragraphs.

Fig. 14. Oblique sections of potato stalks, at left from Verticillium wilt-diseased plants, showing the browning of the vascular (woody) tissues caused by the wilt fungus, and at right from healthy plant.

WILT, *Fusarium oxysporum* Schlecht, and *Verticillium alboatrum* Reinke and Bert. There are two serious wilt diseases in the State caused by distinct organisms, but the two diseases are so similar in appearance and effect that they may both be treated together. Attacked plants may wilt and die comparatively suddenly or they may succumb very gradually, finally dying only a week or two in advance of the unattacked plants in the same field (see cover page). If the stalk of a wilted plant is cut across near the lower end, the interior will be found in most cases extensively browned, whereas in unattacked plants the tissue is normally white (Fig. 14). If a thin slice is cut across the stem end of potatoes produced in a wilted hill, a distinct yellow to brown or black discolored ring, quite different from the normal appearance of the vascular ring which occurs as a faint layer located about ¼ inch beneath the skin, will generally be found present extending into the tuber and following the vascular ring for varying distances depending on the severity of the disease (Fig. 15). Such discolored tissues indicate the presence in the interior of the potato of the organism that caused the wilting, though not all discolored tubers are carriers of the wilt fungus. Out of over twelve thousand tubers from wilted and healthy hills tested in detail during the past few years at Corvallis, only 45 percent of the distinctly browned tubers were as a matter of fact invaded by a wilt fungus, while the other 55 percent were

apparently free of any wilt-producing organisms, though to all appearances the tubers could not be distinguished the one from the other. On the other hand, not all tubers which are invaded by a wilt fungus are discolored; 5 percent of all the tubers examined and having no discoloration were really infected by a wilt-producing organism. This emphasizes the unreliability of depending on a bin examination of the tubers for the determination of the presence of wilt infection in seed potatoes.

Careful Seed Selection Necessary to Avoid Wilt Infection in Tubers. On the average only about half of the tubers in a wilted hill are invaded by the organism which caused the wilting. These, if used for seed, are very likely to give rise to the same disease the following year. Evidently the disease cannot be avoided with any degree of certainty by cutting off and discarding the stem end and planting only the eye end of affected tubers as

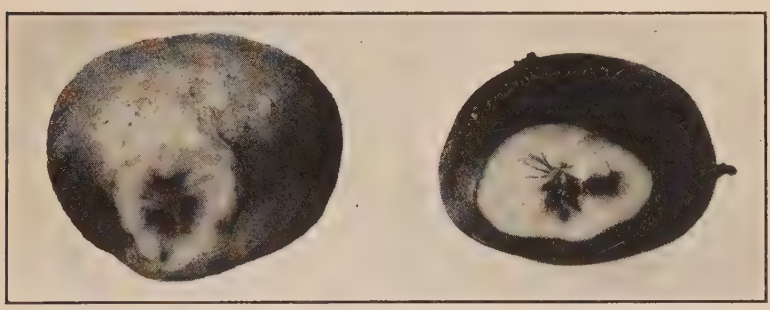

Fig. 15. Discolored vascular tissue at stem end of potato tubers affected with the two wilt-producing organisms which are common in Oregon. Up-to-date tuber affected with Verticillium at left, Early Rose tuber affected with Fusarium at right.

has been formerly stated. This is due to the fact that the fungus responsible for the disease has apparently progressed farther into the tuber than the discoloration of the tissues would indicate. Then too, as mentioned above, it is not possible to determine all tubers affected with wilt merely from their appearance.

These facts just mentioned show that reliance for the control of wilt cannot with confidence be placed on a mere bin sorting of the tubers for seed. Seed treatment is similarly not dependable for wilt control since this will kill only the organisms on the exterior and is not effective in killing the fungus in the interior of the tubers. To avoid wilt in seed potatoes it is by far the best practice to maintain a seed plot as outlined in a previous paragraph and rogue out all diseased plants as soon as they appear. In the case of wilt it is necessary to do this roguing more thoroughly than in the case of most other diseases. This is due to the fact that the disease has a tendency to spread from one plant to another in the row apparently by contact of the root systems. In one test conducted where the wilted plants were not removed during the growing season but were left in the field to the end of the season, thus giving the fungus an excellent opportunity to spread, the first, second, and third plants in the same row away from the original wilted plant carried on the average as high a percentage of wilt infection in the tubers as did the original

wilted plant itself. In order to check this spread of wilt it seems advisable to pull out promptly not only the wilted hill but also the next healthy hill on either side of the wilted one in the same row. By this method the seed plot can probably be freed of wilt in two years' time at most, whereas if only the wilted plants are pulled out, three or more years would undoubtedly be necessary to free the seed stock of this disease.

Crop Rotation Must be Practiced to Avoid Wilt Infection From the Soil. Since the organisms remain alive in the soil for a considerable length of time following the production of a diseased crop, it is necessary to practice long rotations in order to avoid undue infection from the soil. Even then absolute control may not always be secured because one of the organisms,

Fig. 16. Potato tuber affected with nematode, showing numerous small, slightly-raised, pimple-like elevations of surface resulting in a very irregular, roughened, and warty appearance. (Tuber not grown in Oregon.)

Fusarium, in some cases seems to appear more or less indiscriminately in some soils without any obvious relation to the crops grown thereon. This is apparently a minor source of the disease, however, and need not cause much loss where proper attention is paid to the use of the control measures already presented.

NEMATODE, *Heterodera radicicola* (Greef) Müller. This nematode or root knot disease, as it is often called, has fortunately been found only a very few times on potatoes in Oregon. Its seriousness in many other states makes it desirable that the attention of Oregon growers be called to it now in order that

due precautions may be taken to prevent its introduction and establishment on any farms.

On potatoes, as well as on other crops affected, the parasite invades the roots in many different places, giving rise to roundish or irregular enlargements of the roots often called root knots. These may be few or many, depending on the number of individual infections, and may vary in size from a pinhead to a quarter of an inch or more in diameter. As enlargements or swellings of a portion of the root, they are different from the spherical or lobed nodules produced by beneficial nitrogen-fixing bacteria on many leguminous plants which are small or medium in size and attached to the side of the rootlets. Plants rather severely attacked by the nematode on the roots show a general

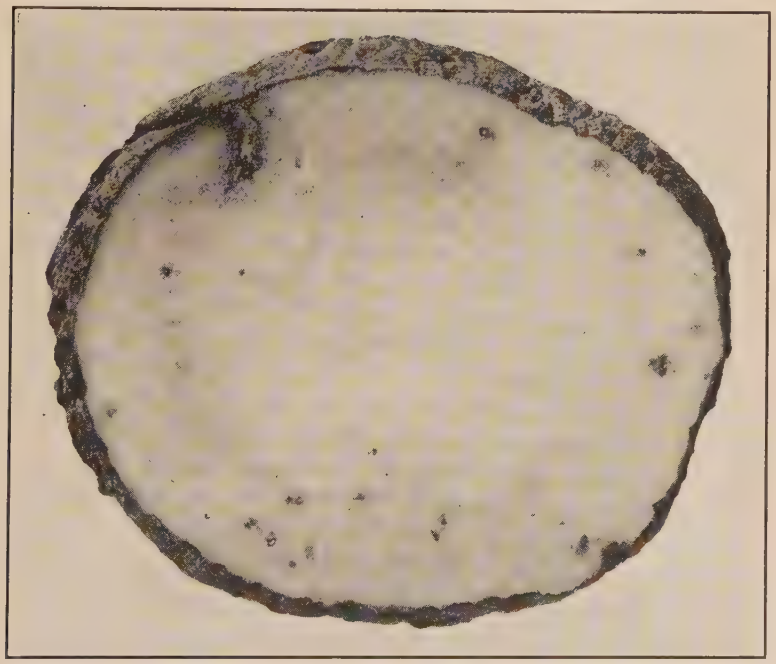

Fig. 17. Section of same tuber affected with nematode as illustrated in Fig. 16, showing many small, circular, brown spots with a pearly white center distributed at irregular distances generally not deeper than a half inch in the tissues. This pearly white center of such spots is the female nematode.

yellowing and stunting of the foliage, leading to a gradual wilting and premature death of the entire plants. Plants less severely attacked may show only slightly stunted growth. At least some of the tubers in a diseased hill are generally invaded by the nematode. Wherever affected, these usually show small, slightly-raised, pimple-like elevations of the surface of the tuber about ⅛ to ¼ inch in diameter, which when abundant produce a very irregular, roughened, and warty appearance (Fig. 16), though tubers only slightly attacked may not show any external evidences of disease. In the tuber tissues at varying distances, usually not more than ¼ inch, beneath such elevations are small circular brown spots usually less than 1/16 inch in diameter with a pearly white center (Fig. 17). This pearly white center of such spots is the

female nematode, which by planting time the following spring is the center of a thriving colony of numerous, newly produced minute nematodes, which, when such tubers are planted, work their way out into the soil and finally into the roots of the young plant again to cause disease.

Parasite Attacks Wide Range of Hosts Besides Potatoes. This parasite attacks a very wide range of commonly cultivated crops and is in general one of the most serious plant diseases known. The classified lists which follow and which with the two following paragraphs were taken from Farmers' Bulletin 648 of the United States Department of Agriculture, include the more important highly susceptible plants. These should never be grown on infested fields or transplanted from any field that may possibly contain the parasite.

Field crops:	Ornamental and drug plants:	Truck crops:	Woody plants:
Alfalfa	Begonia	Asparagus	Almond
Clover	Cineraria	Bean	Catalpa
Cotton	Clematis	Cantaloup	Cherry
Cow-pea (except Iron, Brabham, and hybrids of Whippoorwill crossed on Iron)	Coleus	Carrot	European elm
	Dahlia	Celery	Fig
	Hollyhock	Cucumber	Old World grape-vine
Field pea	Ginseng	Eggplant	Mulberry
Flax	Goldenseal	Garden beet	Peach
Pumpkin	Peony	Garden pea	Pecan
Soy bean	Rose	Irish potato	Persian walnut
Sugar-beet	Sweet pea	Lettuce	Weeping willow
Sugar-cane	Violet	Muskmelon	
Sweet potato		Okra	
Tobacco		Onion	
Vetch		Pepper	
		Salsify	
		Spinach	
		Strawberry	
		Tomato	

Besides the plants listed above, most of the common weeds are attacked by the nematodes, although usually not very severely. Such weeds, however, are a constant source of danger to the farmer, as they help to increase the number of nematodes in the soil. An abundance of weeds is a sign of poor agricultural practice anywhere, but weeds become doubly dangerous where they not only do harm by crowding out other plants and using up food intended for them, but also multiply a pest which may later destroy the crops planted.

Many Economic Plants Free from Attacks of this Pest. Fortunately, many plants of economic importance are known to be free from the attacks of root-knot. At every opportunity, advantage should be taken of this fact in controlling the disease. The following list includes the more important cultivated plants which, so far as known, are seldom or only slightly affected by the nematodes and may be used in crop rotations with the expectation of greatly reducing the number of nematodes in the soil.

Barley	Corn	Pearl millet	Timothy
Beggarweed	Crab-grass	Red top	Velvet bean
Brabham cow-pea	Iron cow-pea	Rye	Wheat
Broom-corn millet	Peanut	Sorghum	Oats

Three-year Rotation with Non-susceptible Crops Necessary to Free Soil of Infestation. Where the nematode has become established in the soil it can be starved out by a good three-year rotation with non-susceptible crops, provided weeds and volunteer plants of susceptible crops are rigidly excluded during this time. As an aid in accomplishing this it is well to have at least some of the rotation crops planted in rows and thoroughly cultivated. The utmost care should be used to insure that the pest is not introduced into the

field in seed potatoes. If the seed potatoes come from an unknown source they should be carefully inspected, and if any infestation is found the entire lot should be rejected for seed. No potatoes from a field known to be infested should ever be used for seed; a mere inspection of the tubers will not reveal all cases of light infection and the introduction of the disease into the field might very readily be accomplished in this way. Care used in avoiding this very objectionable disease will be repaid many fold.

LATE BLIGHT AND ROT, *Phytophthora infestans* (Mont.) de Bary. This disease is known as late blight, because in most sections of the country it attacks the plants most severely comparatively late in the season. In some places, however, and this is true of the Coast Region of Oregon, the disease may appear early, killing the young plants as early as July. The disease has been found a number of times along the Coast in June. The fungus invades the leaves, producing large, dark-brown to black dead areas (Fig. 18), and spreads rapidly through the leaf tissues without forming any distinct rings such as are produced in some leaf diseases. When the disease is severe, even the leaf stalks and tender tissues of the stems are invaded and killed. Under favorable warm and moist weather conditions the disease spreads rapidly both in the attacked leaves and onto other leaves not previously attacked, with the result that all the plants in an entire field may be killed in a very few days (Fig. 19). The diseased and decaying tissues give off a noticeable odor, which becomes quite pronounced in fields heavily attacked. The organism also readily attacks the tubers, producing on them slightly sunken, dark-colored, rotted areas of irregular size, varying from very small spots to areas involving the whole surface of the potato (Fig. 20). At harvest time the rot does not as a rule extend very far into the potato tissues, usually not deeper than half an inch (Fig. 21). In storage, however, it may, and frequently does, finally involve the whole potato with disastrous results, particularly if the temperature is allowed to remain high and the ventilation is poor.

Fig. 18. Late Blight. Dead areas on leaves, showing the usual appearance of the leaves when the disease first attacks them.

Disease Serious only in Restricted Areas in the State. The disease is not serious in all sections of the State, being most serious near the Coast, occasionally destructive in the Willamette Valley and other points west of the Cascades, and rarely, if ever, present to any serious extent east of the Cascades.

Excessive Tuber Rot Frequently Avoided by Delayed Digging. If late blight has been particularly prevalent in the field late in the season, entirely killing many or most of the potato plants, and rot of the tubers is threatened,

it is much better to delay digging the potatoes till two weeks after the potato tops are fully dead, preferably until after a frost has killed the vines. This delay is necessary in order that the numberless spores of the fungus present on and about the old dead plants and on the surface of the soil may die to a large extent before the potatoes are dug. If the potatoes are dug without this two weeks' delay, a large number of them will almost surely become infected by the live spores with which they come in contact during the digging process. Experiments have shown that the smallest percentage of late-blight tuber-rot in storage follows the practice of delayed digging.

Fig. 19. Entire potato plants in the field killed by late blight. (*After Bailey.*)

The large commercial grower must consider his labor supply and other conditions in relation to the time available, and yet delay his digging as much as is consistent with getting the crop out in advance of the rainy season or before frost injury. In the case of the farm home supply, which can be dug in a few days, the greatest advantage can be taken of this means of reducing field tuber infection and subsequent storage rot.

Spraying with Copper Sulfate Sometimes Advisable. In addition to delaying digging for two weeks after the plants are dead it may occasionally be advisable also to spray the old vines and the entire soil surface soon after the heavy attack with a solution of copper sulfate (bluestone) at the rate of 5 pounds in 50 gallons of water in order to kill as many as possible of the spores. In case this is done, thorough spraying of the soil surface is necessary because the spores falling from the plant become very abundantly distributed over the entire soil surface. Whether the spraying of the dead plants and the soil surface before digging is profitable or not will depend mainly on conditions

such as the value of the potatoes, the price of copper sulfate, labor, etc. Whether the soil is sprayed or not, however, the delay of two weeks before starting digging is always advisable under the conditions mentioned.

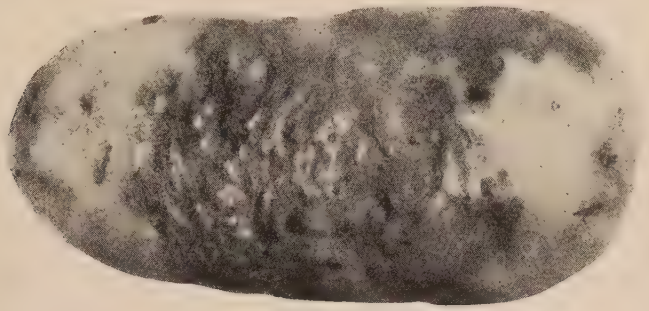

Fig. 20. Tuber showing slightly sunken dark-colored rotted areas due to the late-blight fungus. (*After Bailey.*)

Mowing Potato Tops Sometimes Done. Occasionally some growers use the practice of mowing the potato tops during or following a heavy attack of blight. While no experiments on the value of this method have been conducted here it is conceivable that under some conditions it would help to hold down tuber-rot. A delay of about two weeks following mowing before digging would be necessary to allow the vines to dry completely and the mowing would have to be thoroughly done without disturbing the soil or the tubers to any appreciable extent; otherwise a large amount of rot infection would likely result. If the plants, however, could be left to dry thoroughly after dying without mowing, the results would probably be as satisfactory; or if the spraying with the copper sulfate as outlined above could be done, the results would then probably be more satisfactory than if the tops had been mowed.

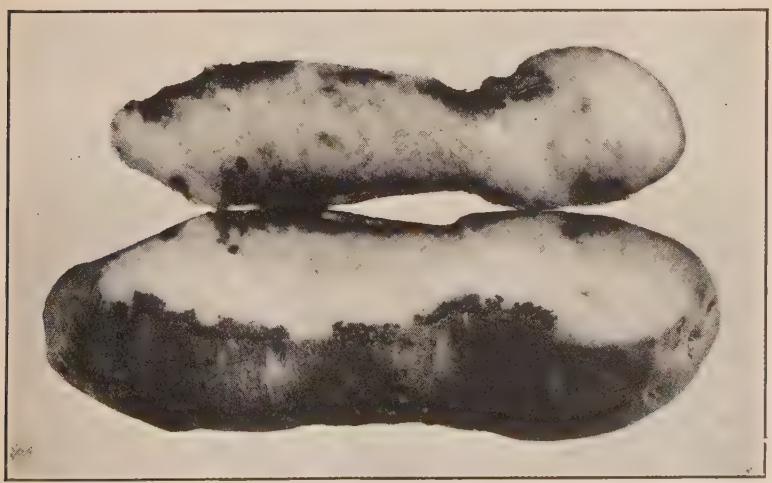

Fig. 21. Section of tuber showing late-blight rot as it usually appears at harvest time.

Diseased Tubers Should be Avoided for Seed and the Crops Well Rotated. Diseased potatoes should not be used for seed, as even a small rotting area not over a quarter of an inch in diameter may carry the disease to the young plant, from which it can readily spread to surrounding healthy plants. In the same way volunteer plants from diseased tubers left in the soil the previous year may serve as a dangerous source for the introduction of the disease to the new crop. To avoid this, crop rotation should be practiced; and for the rotation to be effective volunteer plants must be completely eliminated by good cultivation, etc. Otherwise these volunteer potatoes might perpetuate themselves and also the disease for two or three years in the soil even though the crops were rotated.

Spraying with Bordeaux Mixture the Only Thoroughly Demonstrated, Reliable Method for Control. If the disease does begin to develop in a field, however, it can be successfully controlled if detected soon enough by thorough spraying with bordeaux mixture. Where the disease is generally serious every year, one should commence spraying before the disease ordinarily appears, and continue at intervals of about two weeks during the rest of the season. Where the disease is not generally serious every year the first application of spray might be delayed until the first traces of the disease appear, and if moist weather conditions prevail or the disease takes a new start, the later sprayings may be continued.

That spraying with bordeaux mixture for the control of late blight is satisfactory, effective, and a paying proposition has been repeatedly demonstrated in a large number of eastern states. In New York State, for instance, an extensive series of experiments and demonstrations covering a period of ten consecutive years, during which there were seasons of severe blight epidemics and other seasons when blight did little or no damage, showed conclusively that three to five applications of bordeaux mixture as applied by the average farmer would give an average increased yield to the acre of twenty-five to fifty bushels, while the more thorough applications in experimental plots would give an increase of approximately double this amount. In Vermont the average increase in yield from spraying for 20 consecutive years was 105 bushels an acre. And everywhere that bordeaux mixture has been used on potatoes for blight control over a period of years, the results on the average have always been worth while, so that no one need hesitate to use this material on the ground of effectiveness and reliability. Furthermore it is at present the only thoroughly demonstrated, reliable method for controlling late blight. The practice of regularly spraying potatoes with bordeaux particularly in the bad blight areas should be more widely used in Oregon than it is at the present time.

EARLY BLIGHT, *Alternaria solani* (E. & M.) J. & G. Early blight attacks only the potato leaves, causing brown spots thereon, which as they enlarge develop concentric rings or markings, producing a "target-board" effect. When the spots are numerous, they kill the leaves with a consequent reduction in the yield of the potatoes. In contrast to late blight this disease develops best in warm dry weather. It is not serious in this State but where present can be successfully controlled by thorough and timely sprayings with bordeaux mixture.

WART, *Chrysophlyctis endobiotica* Schilb. This disease has never been found in Oregon. In fact it has only recently invaded any part of the United States and is now known to occur only in rather limited districts in Pennsylvania, Maryland, and West Virginia. It is present in eastern Canada and has caused heavy damage for many years in Europe. Because of its destructiveness and persistence in the soil it is one of the most feared of all potato diseases. It is for this reason that a description of the disease is given here, and it is very much desired that if anyone encounters any suspicious specimens they send them without delay to the Oregon Agricultural College Experiment Station for examination.

Fig. 22. Potato Wart showing brown to black, spongy, rough, warty outgrowths on tubers. (*Cut by courtesy of New Jersey Agr. Exp. Sta. from photo by H. B. Kirk, Pennsylvania Bureau of Plant Industry.*)

The disease known chiefly as "wart" or "canker" is one which attacks the tuber principally, though infection may take place in all the young tissues of the plant, the roots, stolons, stems, and even the leaves. Consequently it is generally not observed until harvesting time. Attacked tubers show brown to black, spongy, rough, warty outgrowths starting usually at the eyes and varying greatly in size though frequently as large as a walnut or even the tuber itself (Fig. 22). In advanced stages the tubers may be wholly covered by this warty growth, having lost every resemblance to potatoes. When this wart-affected tissue is left in the soil it soon becomes broken up and liberates millions of spores, leaving the land badly infected for years. The results of many years of experience and tests conducted in Europe show that occasionally

at least the organism remains alive as long as six years in the soil without in the meantime potatoes having been grown therein. The chief and most reliable means of control lies in the use of immune varieties of potatoes of which there are now several successful ones available.

SCAB, *Actinomyces scabies* (Thaxter) Güssow. Scab is confined in its attack on the potato entirely to the tubers. At first the spots are usually small and brownish but later enlarge into rough, corky, brownish patches (Fig. 23). A single scab spot is usually less than three-fourths of an inch in diameter, although a whole potato may occasionally be covered with scab due to the abundance of individual spots. The organism may also affect other host plants such as turnips, garden beets, sugar-beets, etc., which ought therefore to be avoided as far as possible in rotation with potatoes.

Fig. 23. Scab, showing typical large, irregular scabby areas. (*After Bailey.*)

The disease thrives best on alkaline soils; consequently lime, ashes, and fresh manure tend to increase scab when they are placed on land just before potatoes are planted. These materials, therefore, should be avoided at that time but may often be used with profit with other crops following potatoes. Since poorly drained or wet soils also favor the development of scab, an excess of moisture is to be avoided on potato land. To prevent the introduction of scab on seed potatoes, they should be treated with either formaldehyde or mercuric chloride, and then planted on land which has not grown potatoes for at least three or four years, for the organism remains alive in the soil for a considerable length of time following a crop of diseased potatoes.

POWDERY SCAB, *Spongospora subterranea* (Wallr.) Johns. This disease is quite different in nature from common scab but resembles it somewhat in appearance. On potato tubers in typical cases the spots are at first covered and blister-like, later they break open, forming roundish, raised pustules surrounded by the torn skin of the potato (Fig. 24) and exposing a brownish powdery mass of spores. The spots when mature are generally less than a quarter of an inch in diameter.

This disease is quite serious in Europe and Eastern Canada. It has recently been found in this country in a number of states from Maine to Minnesota and also in Oregon in Clatsop, Tillamook, and Lincoln counties. The disease occurs only in cooler, damper seasons and does not develop when

Fig. 24. Powdery Scab. Spots small, circular, and surrounded by the torn skin of the tuber. (*After Bailey.*)

the temperature is too high. So far it has not proved so serious in the United States as was at first feared. It may never become serious here, but precautions should be used to prevent its spread by not planting infected potatoes. It is not satisfactorily controlled by seed treatment. Long rotations are necessary to rid the soil of the organism when it once gets established.

SILVER SCURF, *Spondylocladium atrovirens* Hartz. This disease is distinguished by the occurrence of irregular brownish areas on the skin of the tubers, which turn silvery and show many fine black points when moistened (Fig. 25). These spots are from ¼ to 1 inch or more in diameter and are usually most abundant on the stem-end half of the tuber. It causes some loss to potatoes in storage by injuring the skin, which permits considerable loss of water and consequent shriveling. It has been encountered in a number

Fig. 25. Silver Scurf. Discolored areas on skin covered with fine black points. (*After Bailey.*)

of places in the State only during recent years, though at the present time it probably occurs in most localities. It is not entirely controlled, though considerably reduced by seed treatment with mercuric chloride. Diseased tubers should be sorted out and not planted, and long rotations should be regularly followed.

DRY-ROT, *Fusarium coeruleum* (Lib.) Sacc. This is apparently the commonest, the most widely distributed, and the most destructive potato tuber-rot in Oregon. It enters the potato generally through wounds and produces large sunken pockets, if only one side of the potato is attacked; or a wrinkled decay, if a large part of the tuber is affected (Fig. 26). Numerous bluish or white points or protuberances are formed on the surface of the decayed parts. This decay often develops extensively during the first month or two after harvest when the temperatures are high. It is not so serious in storage when the storage temperatures are kept low and the ventilation is good. Bruising of the potatoes at harvest time or during subsequent handling should be carefully guarded against. The disinfection of all storage places before storing in the fall is to be especially recommended.

Fig. 26. Dry-rot showing large sunken rotted areas with surface much wrinkled and bearing numerous whitish to bluish protuberances.

Some growers in the State have had excellent results in avoiding this rot by treating the potatoes immediately after digging and before placing in storage, using formaldehyde at the usual strength of 1 pint in 30 gallons of water. On the same farms in other years the rot had been quite destructive. In localities where the average losses from this rot are rather heavy, this method of prevention would be worthy of thorough trial and perhaps regular applications.

POWDERY DRY-ROT, *Fusarium trichothecioides* Wollenw. This rot of potato tubers is in the main serious in Oregon only east of the Cascades. It appears to be limited chiefly to climates having warm dry summers. Affected tubers shrink considerably and often develop in the interior large hollow pockets partly filled with a pink powdery mass of fungous growth (Fig. 27).

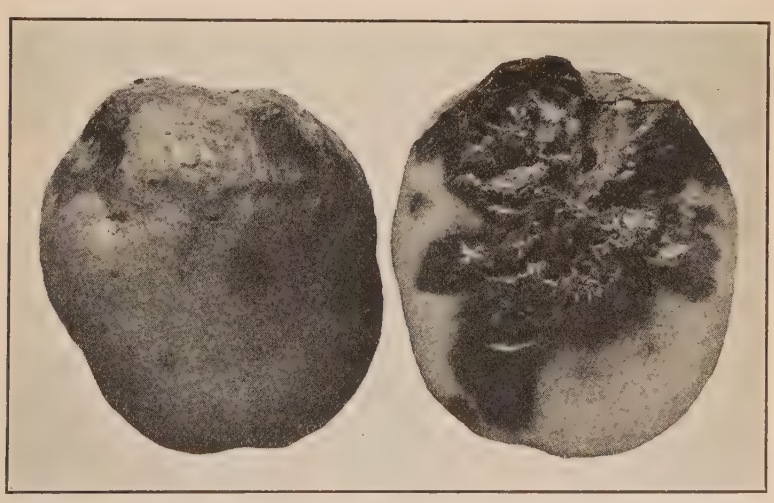

Fig. 27. Powdery Dry-rot, surface and section view of same tuber. Rot extends into tuber in irregular way and commonly hollow pockets partly filled with a pink powdery mass of fungous growth are formed.

Pinkish or whitish tufts of fungous growth are occasionally produced freely on the surface of the sunken, rotted areas. In storage the rot develops at a somewhat lower temperature than do many of the other common rots, though it is not serious if the temperature is kept at from 34° to 40° F. Injury to the potatoes during digging should be avoided, and they ought not to be allowed to remain exposed on the ground very long after they are dug. When dry they should be picked up at once and, as soon as they have cooled, placed, preferably at night or very early in the morning, in cool storage with good ventilation. Where it is necessary to store seed potatoes in a poorly ventilated or improperly cooled storage house, the disease may be effectively prevented by disinfecting the stock, prior to storage, with a solution of mercuric chloride or formaldehyde, provided the disinfecting is done immediately, or within twenty-four hours after digging.

ARMILLARIA ROT, *Armillaria mellea* Vahl. When potatoes are planted on newly cleared land containing much rotting wood or in prune or other

orchards where Armillaria root rot is common, a number of the potato tubers are often attacked by the Armillaria rot. The rotting areas are light brownish, slightly sunken and generally have attached to them a few long black strands which are the rhizomorphs or root-like runners of the fungus (Fig. 28). The interior rotted portion of the attacked potato tuber is composed of alternating layers or flakes of yellowish and white tissue. This rot apparently does not continue to develop in storage, although other fungi commonly gain entrance and complete the destruction of the partly rotted tubers. While the rot is often encountered in the western part of the State the losses are not large. The largest individual loss that has come to our attention was three percent of the tubers grown in an old prune orchard. To avoid this disease potatoes should not be planted on newly cleared land the first year that it is in cultivation.

Fig. 28. Armillaria Rot, characterized by black thread-like strands clinging to the surface of the tubers and by the presence of alternate layers or flakes of yellowish and whitish rotted tissue in the interior. (*After Bailey.*)

STEM-END ROT, *Fusarium radicicola* Wollenw., and other organisms. A stem-end rot, often called jelly-end rot, of potato tubers occurs not infrequently during some seasons in Western Oregon, and to some extent in the rest of the State, while in other seasons it is rarely encountered. It affects only the long tubers and varies widely in type and extent of rot at harvest time from a mere withering unaccompanied by discoloration of the stem end of the tuber as though a part of the water had been withdrawn from that portion, to a dry, wrinkled, sunken, rather tough, and light brown to black discolored condition of a half inch or more of the stem end of the tuber, or to a soft and rather jelly-like, light-brown-colored rot extending back at times an inch and a half from the stem end, the rest of the tuber being sound and unaffected (Fig. 29). In storage these diseased tubers often do not rot further, but the affected tissues frequently dry down, forming a sharp line of demarcation from the sound, unaffected tissues unless stored under conditions unfavorable to the tubers.

The exact conditions which lead to the development of the rot are not known, though it seems possible that when moisture in the soil is deficient in the latter part of the growing season, as is frequently true in Western Oregon, the plant might actually withdraw water from the stem end of the tuber giving a sunken withered condition favorable to the entrance of various organisms both saprophytic and parasitic, which soon give rise to the rot. At any rate the rot develops in the crop without any apparent relation to the condition of the seed potatoes at planting time or to crop rotation, and for the present no special measures for its control can be definitely recommended. The rot can no doubt be avoided to a considerable extent, however, by the maintenance of a uniform and adequate supply of moisture in the soil throughout the season.

Fig. 29. Stem-end Rot of potato tubers as it usually occurs at harvest time.

DISEASES DUE TO UNKNOWN CAUSES

During recent years a number of diseases of potatoes not yet proved to be due to any parasitic organisms have been receiving increasing attention by growers and investigators alike. The cause of these diseases is obscure and to the present time has baffled the many careful investigations conducted to determine this point. For convenience these diseases are grouped here under causes unknown. In this group come mosaic, curly dwarf, leaf roll, spindle sprout, and net necrosis. Some of these are widely distributed in America and are causing great reductions in yields. A number of them are present to a serious extent in this State. They are transmitted from year to year in the tubers, though their presence, with the exception of net necrosis, can be determined only by an examination of the growing plants in the field, as there are no indications of the diseases in the tubers. Diseased potatoes appear to

run out entirely and after a few years fail to produce any yield. In addition to being carried in the tubers from diseased hills, the diseases are propagated year after year by their spread to adjacent healthy plants in the field. This spread is frequently accomplished through the aid of sucking insects and possibly other means not now known, and is not always readily prevented.

Only healthy potatoes from normal hills should be kept for seed. If a field shows a large number of plants affected by these diseases, however, no potatoes should be used from it for planting the next year, but the seed should be secured from fields free of these inherited weaknesses. The most rigid care should be exercised in excluding these troubles from the seed plot.

Fig. 30. Mosaic diseased plant, variety Eureka, at left, healthy plant of same variety at right; both grown in greenhouse. (*After Orton.*)

MOSAIC. This disease is characterized by a mottling in the green of the leaf, in which yellowish or light-colored areas alternate with the normal green, and is accompanied generally by a crinkling but not a rolling of the foliage (Fig. 30). Diseased plants tend to have a stiff, erect appearance and are from slightly to considerably stunted depending on the severity of the attack. Figures available show that the yield in the average affected hill is reduced one-third and in badly affected hills approximately one-half as compared to normal hills.

This disease is widely distributed in Oregon and has been seen severely attacking upwards of 65 percent of the plants in some fields. It is of such a nature that particularly in light cases many growers overlook it entirely and are not aware of its presence though it may be causing considerable reduction of the yield. The only way in which it can be avoided is by the selection for seed purposes of tubers from healthy plants. This is best accomplished in the seed plot, where during the growing season the disease can be recognized and should be removed by roguing promptly and rigidly to prevent its spread to other plants. It cannot be eliminated merely by a bin sorting of the tubers

as there is no visible abnormality in the tubers; they are perfectly normal in appearance. It is due time that the growers pay more attention to this type of disease, learn to recognize it readily, and take the necessary steps to avoid the losses that are now occasioned through its almost entirely unchecked ravages.

CURLY DWARF. The stems, branches, and leaf veins of plants affected with curly dwarf are shorter than normal, giving the plants a dwarfed, bushy, and crinkled appearance, accompanied at times by a pronounced curling and wrinkling of the foliage (Fig. 31). This may occasionally be merely an advanced stage or extreme case of mosaic. The yields from diseased plants are very small.

LEAF ROLL. The occurrence or establishment of this disease in Oregon is still somewhat in doubt, although it is said to be important in a number of other states. Diseased plants are described as having an upward rolling of the leaves on the midrib, giving the leaves a tubular form and the plant a stiff, erect appearance. Occasionally the plants are bushy and are almost always pale in color. The lower leaves of attacked plants are always rolled, leathery or brittle, often dying from the tips backwards. Other leaves may roll also. The plants are more or less dwarfed. The yields are generally very small and the tubers are usually though not always attached close to the stem.

Fig. 31. Potato Curly Dwarf, showing dwarfing, reduction of foliage, and absence of tubers. (*After Orton.*)

SPINDLE SPROUT. In this disease numerous slender spindling sprouts are produced by the affected tuber when planted (Fig. 32), none of which succeed in producing a large plant or any appreciable yield. Occasionally the disease can be distinguished by the appearance of the sprouts on the tubers before planting and where possible should always be sorted out. From observations, it seems probable that the abnormality is induced at times by several very different factors which so weaken the tubers as to give rise to this peculiar growth of the tops. Among the factors probably responsible for the development of this trouble may be mentioned excessive heat and drought during growth of the tubers, freezing or too cold storage of the tubers in the preceding winter, and insufficient ventilation of the tubers during storage.

NET NECROSIS. This disease is characterized by the production of an extensive network of small brown strands of discolored tissue extending

throughout the interior of the potato tuber tissue though occurring more abundantly in the tissues near the surface of the tubers (Fig. 33). Recent experimental work in the East shows that it is closely associated with and is apparently a symptom of leaf roll. Tubers from leaf-roll plants and tubers showing net necrosis should therefore be avoided for seed.

In some cases a condition indistinguishable from this hereditary net necrosis is brought about by chilling or frosting of the tubers which should then be called frost necrosis. This frost necrosis is not transmissible in the

Fig. 32. Spindle Sprout. None of the spindling stalks developed are able to produce a strong plant. (*Photo by Bailey.*)

seed potatoes, though affected tubers should be avoided as seed, due to the chance of confusing them with potatoes affected with the true net necrosis and also with wilt, which they slightly resemble.

Fig. 33. Net Necrosis. The netting is typically more abundant in the tissues near the surface than in those deeper in the tuber. (*Photo by courtesy of U. S. Department of Agriculture, Bureau of Plant Industry.*)

DISEASES DUE TO CLIMATIC OR ENVIRONMENTAL CONDITIONS

This group includes tip burn, internal brown spot, black heart, hollow heart, and enlarged lenticels. These diseases or abnormalities are not inherited but depend for their development on unfavorable conditions.

TIP BURN. Tip burn is a drying and dying of the leaves, beginning at the tips and margins and working inward. The leaves often roll; becoming brown, they present a scorched appearance (Fig. 34). This trouble is usually most pronounced on light soils and during hot, dry periods, often following insect injury. If possible, an adequate soil-moisture supply should be maintained by irrigation or careful cultivation. This disease can be largely prevented by timely spraying with bordeaux mixture, due probably to the shading effect which this spray has on the foliage of the potato plant.

Fig. 34. Tip-burn. A drying and dying of the margins from the tips backwards accompanied by an upward and inward rolling of the leaflets.

INTERNAL BROWN SPOT. The development of irregular brown spots in scattered and irregular places in the interior of potato tubers (Fig. 35) is known as internal brown spot. These brown spots are free from bacteria or fungi and represent merely groups of cells which have died from some cause or other. This disease is generally believed to be due to lack of water at some period during the growth of the plants, perhaps as the result of poor soil or merely insufficient soil moisture. The trouble is not transmissible in the

tubers. Affected potatoes are, however, generally avoided for seed on account of the chance for predisposition of the affected potatoes to this disease.

BLACK HEART. The disorder of potato tubers known as black heart is distinguished by the occurrence in the center of the tuber of an irregular

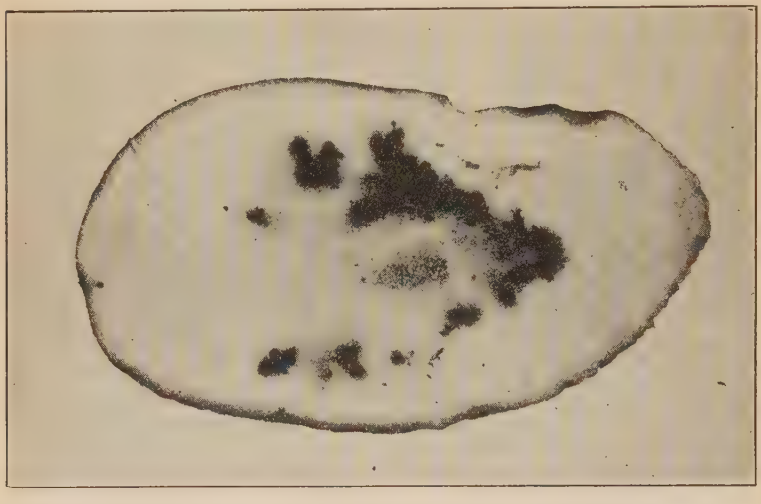

Fig. 35. Internal Brown Spot. Irregular brown spots or groups of cells which may occur at any place within the tuber.

area of jet black, quite moist, and flabby tissue (Fig. 36). Occasionally the discoloration may occur as a black ring near the center inclosing a gray or darkened area. In advanced stages, the tubers show hollow, black-bordered cavities in the center. The discoloration progresses outward and whenever it reaches the outside, as occasionally happens, a rapid decay sets in.

Fig. 36. Black Heart. An irregular area of black, moist, flabby tissue in the center of the tuber. Occasionally the discoloration may occur as a black ring near the center inclosing a gray or darkened area.

Black heart is produced when potatoes are heated to 100° to 110° F. for a few hours or stored at lower temperatures in piles deeper than six feet without ventilation from the sides or bottom. This type of trouble is most frequently encountered in shipments of potatoes which have been overheated in transit, in bins where the ventilation is unusually poor, and in seed potatoes that are taken out of storage and exposed to too high temperatures in the sun for too long a period while they are being prepared for planting.

HOLLOW HEART. This is a name applied to potato tubers that have a conspicuous cavity in their center. The cavity is usually present without any discoloration of the surrounding tissues though occasionally the adjacent cells assume a brownish, corky appearance. This abnormal condition is confined commonly to the large tubers and occurs mainly in seasons or under conditions favorable for rapid growth. On soils where the trouble is apt to appear it can be very largely if not entirely avoided by closer spacing of the plants, which will prevent such rapid and uneven growth of the tubers and the tendency of the tubers to split.

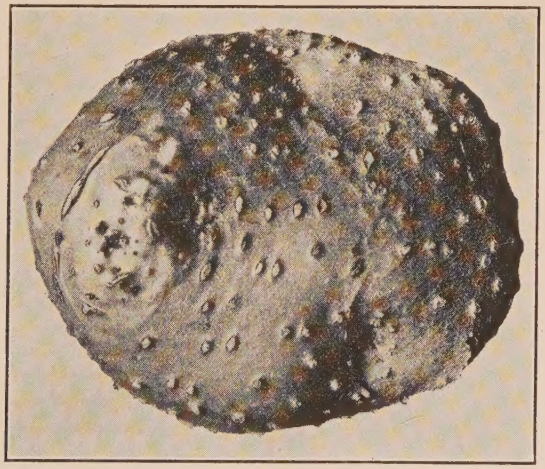

Fig. 37. Enlarged Lenticels. Small scab-like openings in the skin filled with light or cream-colored growths of cells appearing as though pushed out from below.

ENLARGED LENTICELS. Potato tubers left for some time in very wet soil or stored after digging in a very moist atmosphere will frequently develop a large number of small scab-like openings in the skin filled with light or cream-colored growths of cells appearing as though pushed out from below and which frequently assume a corky appearance in older stages or when exposed to air for a few hours after digging (Fig. 37). These are merely abnormally developed lenticels which when natural appear as small inconspicuous slits scattered over the surface of the tuber. Excess moisture is the commonest cause of the unnatural growth of these lenticels. Occasionally this condition is mistaken for scab to which there is only very slight resemblance when both are carefully examined.